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Combustion Sintering Process

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[Article by Mitsue Koizumi, professor of Ryukoku University, and Kinsei Miyamoto, assistant professor of Osaka University]

[Text] **1. Preface**

The combustion sintering process is a new sintering process. It synthesizes and finely processes ceramics by combining the combustion synthesis process (Self-Propagating High Temperature Synthesis or Combustion Synthesis)[1,2]—an exothermic synthetic reaction of compounds—with various pressurizing methods.[3] The manufacture of new materials using the combustion synthetic reaction widely ranges from synthesizing of ceramics powder, simultaneous combustion sintering, forming, joining, coating, to TiNi and TiAl alloy synthesizing, etc. In Japan, the Society for the Research of Combustion/Synthesis was founded and R&D in this field is being carried out extensively.

In October last year, the first international symposium on sintering and synthesis was held in San Francisco as a part of the U.S. Ceramics Academic Society Pacific Area Meeting and researchers from countries such as the United States, Japan, and the USSR met. Professor Merjanov [phonetic] of the USSR, a pioneer of combustion synthesis, was invited and for the first time met the researchers of Western countries. Thirty-eight theses (eight from Japan) were publicized in 3 days. There was a growing interest particularly in combustion sintering or forming and many unique research projects were reported in these fields. Research projects publicized at the above symposium are scheduled to be published around June this year in the form of a collection of theses.

In the USSR, development of the combustion sintering process appears to have been carried out for these 12 or 13 years. In the Western countries, particularly in Japan and the United States, development of the combustion sintering process was started 5 or 6 years ago. Although a part of the processes developed has already been put into practical use, many processes are still in the R&D stage. In this paper, the current status of development of combustion sintering process in the world, particularly in Japan, the United States, and the USSR, is reported and the future outlook is discussed.

2. Development of Combustion Sintering Process

In the combustion sintering process, a high reaction heat ranging from 2000°C to 3000°C is emitted with the propagation of synthesizing reaction of particles. Then, at least some of the materials and products are melted and finely processed by pressurization. Figure 1 shows an outline of such a process. Materials capable of being sintered contain compounds having a high heat of formation resulting in exothermic reactions. An example is

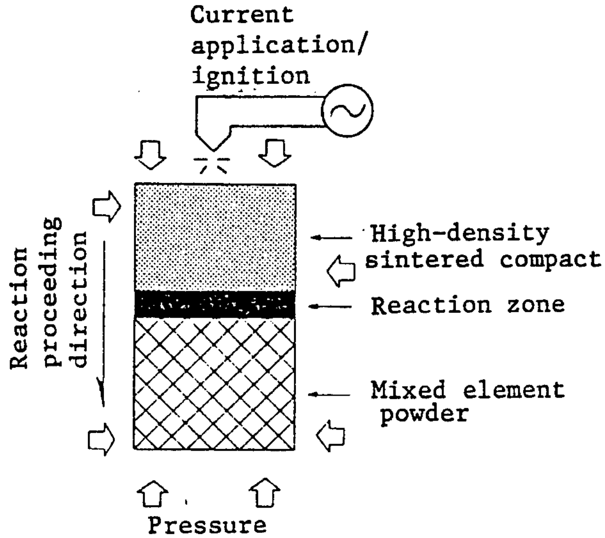

Figure 1. Pressurizing Combustion Sintering Process

given in Table 1. The above materials include high-temperature materials and antifriction materials in large quantities.

The combustion sintering process can be deemed to be a kind of reaction sintering and is characterized by the fact that it possesses the following advantages, unlike the conventional sintering processes.

1) Synthesizing and fine processing of ceramics can be carried out by a one-step process.

2) Reactions can be completed in seconds.

3) Long-time external heating at high temperatures is not required.

4) Compounding between ceramics materials or between ceramics materials and metals can be achieved in various forms.

There are several problems to be solved to ensure that the combustion sintering process can be used as a practical process. One such problem is to develop any pressurizing method permitting pressures to be applied

Table 1. Example of Combustion Sintering

TiC	SiC	TiB_2	TiB	ZrB_2
NbB_2	$MoSi_2$	$TiSi_2$	TiNi	TiAl
NiAl	CoAl			
$2Ti + 2B + C \rightarrow TiC + TiB_2$				
$3TiO_2 + 4Al + 3C \rightarrow 3TiC + 2Al_2O_3$				
$TiO_2 + Zr + C \rightarrow TiC + ZrO_2$				
$3SiO_2 + 4Al + 3C \rightarrow 3SiC + 2Al_2O_3$				
$WO_3 + 2Al + C \rightarrow WC + Al_2O_3$				

effectively and economically during reactions proceeding at high speed. If pressures are not necessary, an extremely simple combustion sintering process may be established. It is difficult, however, to currently achieve the manufacture of materials having a high density without pressurization because a volumetric shrinkage of 20 to 30 percent essentially takes place when raw materials are converted to products by combustion synthesis and a maximum volumetric shrinkage of 50 percent takes place when green compacts of raw materials are converted to products. The pressurizing process, therefore, is required to be provided with responsiveness capable of following a rapid volumetric shrinkage and finely processing products by removing pores. As such a pressurizing process, uniaxial pressurization using hot pressing and spring loads, isotropic pressurization using gas and liquid pressures, and processes using impact compression and centrifugal force are being actively developed. The current status of combustion sintering processes using the various above-mentioned pressurizing methods, therefore, is described below.

A. Uniaxial Pressurizing Process

Using the hot pressing method, materials are pressurized to several hundred atmospheres. The material temperature is then raised to the reaction starting temperature or a higher temperature and thus the materials are synthesized and sintered. Such a process has already been developed by the U.S. Corning Glass Corp.[4] Various composite materials containing Al, Ni, Fe, AlN, Al_2O_3, ZrO_2, WC, etc. on the basis of TiB_2 having a high heat of formation and materials obtained by laminating these composite materials are being manufactured. As raw materials, TiH_2, TiO_2, AlB_2, NiB_2, B_2O_3 powders are used. For example, composite materials having a high density can be obtained by exothermic reactions such as the following:

$TiH_2 + AlB_2 \rightarrow TiB_2 + Al + H_2$
$TiN + AlB_2 \rightarrow TiB—AlN$
$3TiO_2 + 3B_2O_3 + 10Al \rightarrow 3TiB_2 + 5Al_2O_3$

The uniaxial pressurization process using hot pressing is being also developed by the U.S. W. R. Grace Corp., and TiB_2, TiC, TiB_2 + TiC group high-density materials are being manufactured.[5] The above processes appear almost to have reached a practical-use level.

Meanwhile, as a process improving the continuous pressures, the spring-loaded process has been devised by Sata et al. of the Tohoku Technical Engineering Laboratory and is being used to develop TiB_2-Cu group functionally gradient materials.[6] Figure 2 shows a sketch of this equipment.

The U.S. General Science Corp. is also developing the same process and has obtained a TiB_2 material (150 mm^2) having a density of 98 percent.[7] The uniaxial pressurizing process is simple and economical. The shape of materials, however, is limited to only plate.

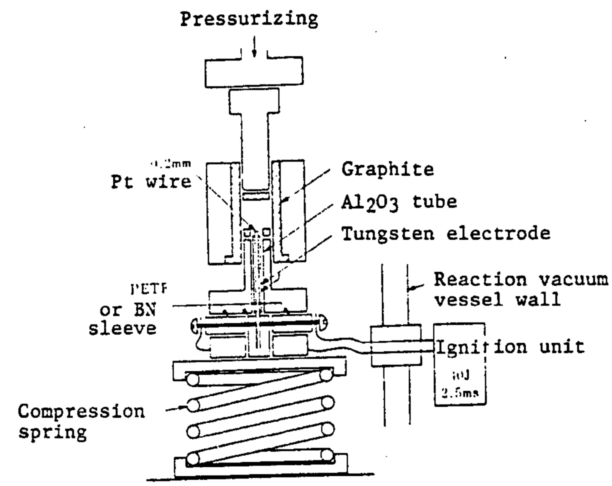

Figure 2. Spring Compression Forming Process[5]

B. Isotropic Pressurizing Process

The isotropic pressurizing process using glass compression, as in the case of the hot isostatic process (HIP), is superior in the responsiveness of pressures and can manufacture comparatively large-sized materials having a complicated shape. Figure 3 shows test equipment (being developed by the Osaka University) used for gas pressure combustion sintering.[8] A heated and degassed material compact is sealed in a Pyrex glass capsule. This process is the same as the HIP capsule process. It appears possible to use metals as capsule materials. Materials are ignited by the heat generated with an ignition agent located around the capsule. BN powders are sprayed (for coating) to the material compact and capsule to prevent the reaction of the capsule with the material and ignition agent. The ignition agent consists of powders for combustion synthesis. If a sufficient calorific value can be secured, any types of materials may be used as ignition agents. It is possible to select inexpensive powders or powders whose products can be used as ceramics powder. Ti and C mixed powders are currently used as an ignition agent; the exothermic temperature of such an ignition agent reaches 3000°C. Argon or nitrogen is used as a pressure medium gas.

Materials are ignited in the following manner: The temperature of the inside of a high pressure vessel is raised to about 700°C and the glass capsule located inside the vessel is thereby softened. Then, argon gas pressures are applied to the glass capsule up to a maximum of 100 MPa and an electric current of 100A is applied to the ignition heater for 3 seconds. Thus, the combustion sintering of the raw material is started by the heat generated by the combustion synthetic reaction of the ignition agent. Figure 4 [not reproduced] shows a material compact used to burn and sinter TiC + 20 wt%Ni composite ceramics, material compact sealed in a glass capsule, and sintered compact. Figure 5 [not reproduced] shows a fracture structure of a TiC + 10 wt%Ni

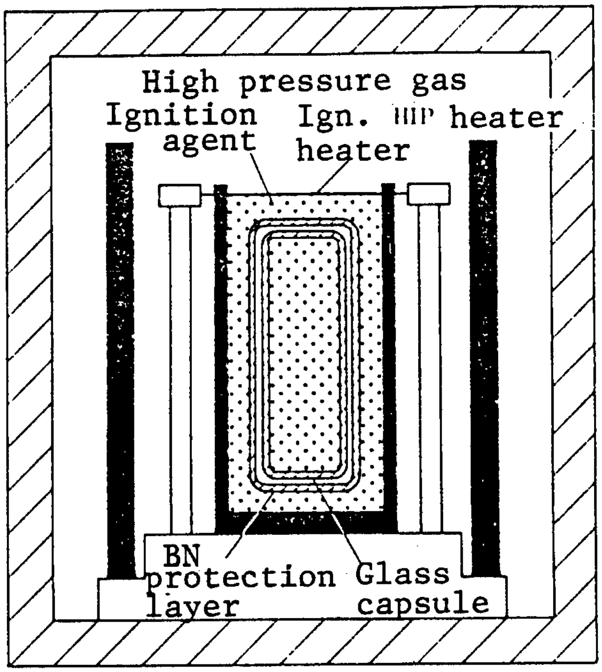

Figure 3. Gas Pressure Combustion-Sintering Test Equipment

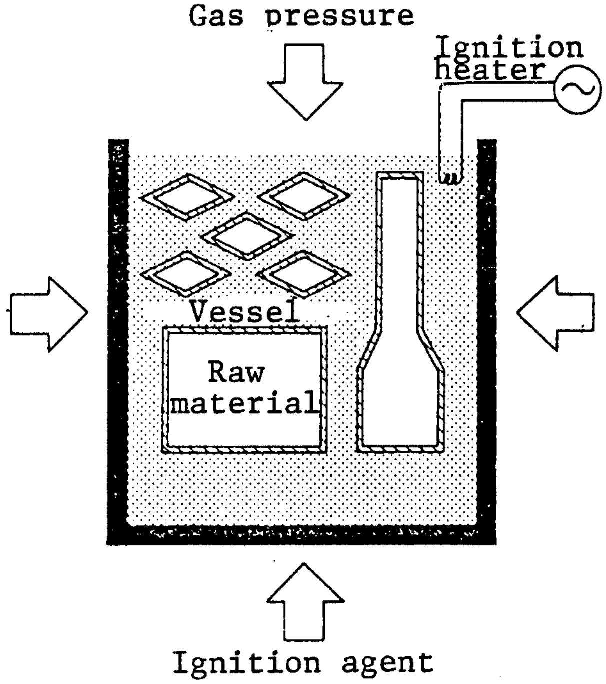

Figure 6. Schematic Diagram of Gas Pressure Combustion Sintering as a Production Process

composite ceramics almost completely fined. The Vickers hardness of such composite ceramics was 22 GPa.

In the case of the above ignition method, the use of an ignition agent allows several samples to be ignited concurrently, thus theoretically enabling the mass production of products. Figure 6 shows a model of gas pressure combustion sintering as a production process.

Generation of heat by ignition agent allows reactions to be carried out completely. In addition, even in the case of materials whose heat of formation is low, combustion synthesis readily takes place. The isotropic pressurizing process, therefore, can be applied to a wider range of material groups and a combination of such groups.

The hydrostatic process using water as a pressure medium instead of gas pressure is being developed by the Tohoku Engineering Technology Laboratory.[8]

Combustion synthesis is a reaction not accompanied by generation of gas. However, additives, moisture, and other impurities, where they are present, are gasified due to high-temperature reactions and fine processing is sometimes hindered. Where reactions are carried out using a sealed system, such as the isotropic pressurization process, it is particularly necessary to carry out pretreatments such as selection of additives and heating/degassing.

AlN can be synthesized by nitriding and burning Al powders. In this case, if a high nitrogen pressure of 100 to 300 MPa is used, AlN having a density of 92 to 97 percent can be synthesized. Such phenomenon has been reported by Holt, doctor of the U.S. Lawrence Livermore National Research Institute.[9] It appears that 1 to 2 percent of Al remains in the synthesized AlN. AlN each having a grain size of about 5 μm and a hardness of 12 GPa has already been obtained. In this case, it is presumed that the decomposition of AlN is prevented by raising the nitrogen pressure and that AlN is synthesized and finely processed by gas compression in a melted state. In the USSR, high-density BN having a diameter of about 100 mm has already been synthesized. The same process as that used by Dr Holt is presumed to have been used in the USSR.

C. Impact Pressurization Process

In the U.S. Army Ballistic Trajectory Research Laboratory, TiB_2 and TiC are synthesized in the following manner: While the product is still placed in a high-temperature state immediately after combustion waves have traveled, an impact pressure is applied to the product using gunpowder to finely process the product.[10] Sintering of general ceramics powders by applying an impact pressure caused cracks to occur in the sintered compact. This is a weak point of the impact-pressurization process. It appears, however, that the use of reaction heat permits this disadvantage to be avoided.

Sawaoka et al. of the Tokyo University of Engineering have developed a process of manufacturing high density SiC without cracks by applying an impact pressure after arranging, for example, Ti and C combustion agents around an SiC powder compact.[11] It appears that the combustion agent is ignited by an impact temperature and the resulting reaction heat effectively acts on sintering.

D. Centrifugal Force Process

Odawara of the Tokyo University of Engineering and the Tohoku Engineering Technology Laboratory have developed a ceramics composite structure tube manufacturing process, in which Thermit reactions are combined with centrifugal force.[12] A Thermit agent consisting of a mixture of Fe_2O_3 and Al powders is applied to the internal wall of a metal tube and the tube is ignited by rotating it at a high speed of about 100 G. Thus, a composite Al_2O_3/Fe/metal pipe is formed by high-temperature explosive reactions. The innermost Al_2O_3 layer is finely processed, i.e., 5 percent or less in porosity and, therefore, the composite pipe is used as a lined pipe superior in corrosion resistance, heat resistance, and abrasion resistance. Figure 7 [not reproduced] shows an actual composite pipe. This centrifugal Thermit process has been put into practical use by Kubota Ltd.; large-sized composite structure pipes, each having a size of 300 (diameter) x 500 mm have already been manufactured. The same manufacturing process has been developed in the USSR, though the pipe size is slightly smaller.

Thus, combustion sintering processes in which various types of pressurizing processes are combined with each other have been developed. It is not necessary, however, to discuss the merits and demerits of each process. Materials having more diversified properties should be developed by effectively utilizing the specific features of the individual processes.

Meanwhile, SiC-C composite materials have been recently manufactured by permeating melted Si without applying pressures.[13] In this process, Si powders are put on a porous carbon compact. If Si is melted by electric sparks or heating, melted Si penetrates into the carbon compact by capillary actions and causes combustion reactions with carbon to synthesize SiC. Thus, when melted Si penetrates to a certain depth while synthesizing SiC, a βSiC-C compact is synthesized. The above SiC-C composite materials have been developed by Osaka Cement Co., Ltd. and are marketed under the brand name of CARBO-SiC (Figure 8 [not reproduced]). The porosity of the above materials is several percent and the change in dimensions is small, i.e., 0.6 percent. The mechanical strength, abrasion resistance, and oxidation resistance of CARBO-SiC have been improved with good conductivity of electricity/heat and lubrication ability (that carbon materials possess) maintained.

3. Development of Materials by Combustion-Sintering Process

The combustion-sintering process is a unique process which can concurrently synthesize and sinter ceramics. Is it really possible to manufacture superior materials by the combustion-sintering process? No definite answers have yet been given to this question. However, as in the case of ceramics composite structure pipes manufactured by the centrifugal Thermit process (already put into practical use) and CARBO-SiC, it is highly possible that the combustion-sintering process can manufacture a variety of composite materials consisting of ceramics-ceramics and ceramics-metals. In the combustion-sintering process, synthesizing reactions take place concurrently with fine processing. As a result, a microscopic structure completely different from that of the conventional compound sintered compact appears. Thus, superior properties can be expected. Furthermore, it is possible to combine various materials with forms.

A microscopic structure of a TiC + Al_2O_3 compound sintered compact synthesized by compound reactions given in Table 1 is shown in Figure 9 [not reproduced], as an example of structure control.[14] In this case, the sample underwent self-combustion and sintering at an extra high pressure of 3 GPa (arising from the compression of solids) and was finely processed to 95 percent. Also, the sample can be almost completely finely processed by combustion and sintering using gas pressures. The black portions shown in the figure are Al_2O_3 and the white portions are TiC. The grain size of both Al_2O_3 and TiC is small, i.e., 1 or 2 μm. The compound-sintered compact shows a structure with a noticeable feature in which TiC and Al_2O_3 areas are complicatedly entangled with each other. The sintered compact has a hardness of 22 to 25 GPa. Raw materials such as TiO_2, Al, and C are comparatively inexpensive and fine powders can be used. These are the advantages of the combustion-sintering process.

It proves to be effective to add ceramics powders (same as or different from the product) to raw materials. By doing so, a more microscopic structure is formed and mechanical properties are improved. For example, if TiC is added to Ti + 2B mixed powders, TiB_2-TiC composite ceramics having a microscopic structure (grain size: 5 μm or smaller) is synthesized. Figure 10 shows a behavior of improvement in the Vickers hardness in the above case.[15] The addition of TiC powders serves to dilute reaction heat and also to control the growth of TiB_2 grains by dispersion.

It is also possible to distribute the metal phase in a gradient-composition manner. In such composition control, dispersion does not extend over a wide range because combustion-synthesis reaction is an extremely short time process and a compound structure almost equal to the material composition arrangement can be expected in the manufactured sintered compact. The sintered compact can be used to create so-called "functionally gradient materials." Functionally gradient materials used as ultra-heat-resistant structural materials are receiving much attention; they are the next generation high-temperature materials that can readily achieve joining with metals through toughening by thermal stress relaxation.[16,17] In the case of research organizations founded based on the expenses for science and technology promotion coordination being implemented from 1987, the development of TiB_2-Cu group functionally gradient materials is being carried out by the Tohoku Engineering Laboratory. Development of TiB_2-Ni and TiC-N_2 group materials is also being carried out by the

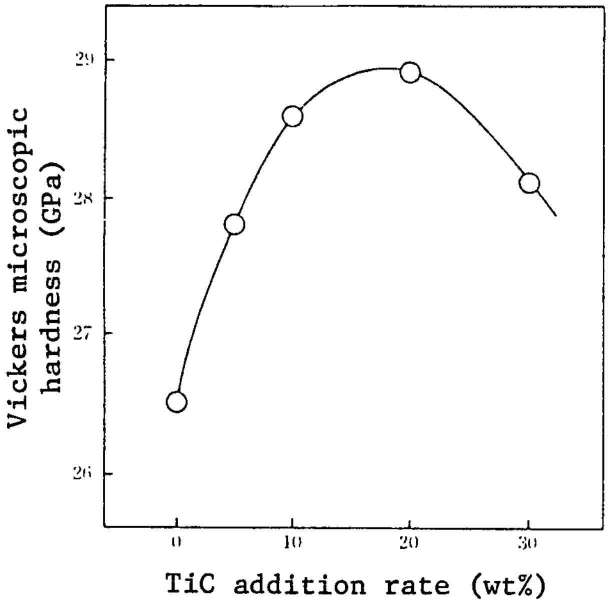

Figure 10. Hardness of TiB_2-TiC Composite Ceramics

Osaka University. Figure 11 [not reproduced] shows a structure of the TiB_2-Cu group functionally gradient material. A variety of material compounding processes are arranged as shown in Figure 12. As shown in Figure 12, such processes as use of compound reactions, addition of ceramics powders, addition of metal powders, distribution of ceramics powders and metal powders in a gradient-composition manner, and a combination of these methods can be conceived. Furthermore, these materials can be processed to a variety of shapes using various pressurizing processes. In other words, the combustion-sintering process is used to melt and compound various types of raw materials and products by the ultra-high-temperature process in which a thermal energy of 2000 to 3000°C or higher temperatures is self-generated. It can be said to be a ceramics alloy manufacturing process.

4. Conclusion

As a promising technology for the manufacture of new composite materials, the combustion-sintering process has been introduced in this paper. However, in order for the combustion-sintering process to be used for the manufacture of new composite materials, it is necessary to further improve the pressurization process and to develop reaction and structure control technologies. As these requirements are satisfied, the combustion-sintering process will make great progress as a process for manufacturing more diversified composite materials.

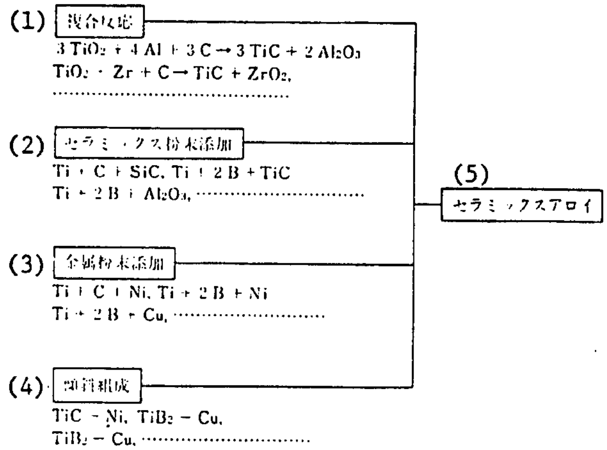

Figure 12. Ceramics Alloy Manufacturing Process Using Combustion-Sintering Process

Key:—1. Compound reaction—2. Addition of ceramics powder—3. Addition of metal powder—4. Gradient composition—5. Ceramics alloy

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Regarding 3, 4, 6, 8, and 9 literature and other literature, refer to Proceedings of the International Symposium on "Combustion and Plasma Synthesis of High Temperature Materials," American Ceramic Society, scheduled to be published about June 1989.

Special Processes for Ceramics

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[Article by Masaya Miyake, doctor in engineering and deputy manager of Electronic Parts Development

Table 1. Removal Machining Methods Classified by Supply Energy[1]

Mechanical	Abrasive grain machining	Machining using bonded abrasive grains; Machining using sprayed abrasive grains	1) Grinding
			2) Honing
			3) Superfinishing
			4) Abrasive-cloth machining
			5) Barrel machining
			6) Lapping
			7) Ultrasonic machining
			8) Polishing
		Machining using free abrasive grains	9) Viscoelasticity-fluidized machining
			10) Blast machining
	Machining using single tool		11) Cutting
			12) Dividing
Chemical			13) Etching
			14) Chemical grinding
Photochemical			15) Photo etching
Electrochemical			16) Electrolytic polishing
Electrical			17) Electric-spark machining
			18) Electron-beam machining
			19) Ion machining
			20) Plasma machining
Optical			21) Laser-beam machining

Department of R&D Division, and Takao Nishioka, researcher of same department, Sumitomo Electric Industries, Ltd.]

[Text] **1. Preface**

Fine ceramics such as Si_3N_4 (silicon nitride), SiC (silicon carbide), and ZrO_2 (zirconia) are receiving much attention as new materials having superior properties exceeding the limit of conventional metal and plastic materials. However, there are many problems to be settled in order for fine ceramics to be put into practical use in wider fields. Of such problems, difficulty in machining can be cited as the most important problem. In other words, the advantages of fine ceramics, i.e., high strength and high hardness concurrently serve as a disadvantage, i.e., difficulty in machining. This, therefore, has resulted in an increase in machining cost and limited processable shapes and is greatly interfering with the practical use of fine ceramics. In spite of the above problems, there is a growing need to use ceramics as complicatedly shaped structural materials utilizing their specific features, such as superior abrasion resistance, corrosion resistance, and low thermal-expansion coefficients. A strong request, therefore, is being made for the establishment of highly efficient and low-cost machining techniques applicable to complicated shapes as well as three-dimensional shapes.

Table 1 presents removal machining methods (being currently applied to ceramics materials) classified by supplied machining energies.[1] In this paper, an outline of specific machining techniques for ceramics is described with emphasis laid on ultrasonic machining, electric-spark machining, and laser-beam machining. Many types of ceramics materials have so far been insulating materials and electric-spark machining could not be applied for machining ceramics materials. Research on providing ceramics materials with conductivity has recently been carried out and materials which can be machined by electric sparks are being developed.[2] In this paper, therefore, examples of electric-spark machining are described in detail with emphasis laid on the ceramics materials which can be machined by electric sparks.

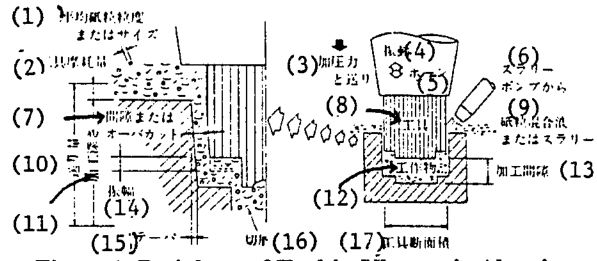


Figure 1. Periphery of Tool in Ultrasonic Abrasive-Grain-Crushing Machining[3]

Key:—1. Average abrasive grain size—2. Tool-abrasion rate—3. Pressurizing force and feed—4. Vibration—5. Hone—6. From slurry pump—7. Gap or overcut—8. Tool—9. Abrasive-grain-mixed liquid—10. Feed—11. Machining depth—12. Workpiece—13. Machining gap—14. Amplitude—15. Taper—16. Chips—17. Tool sectional area

2. Ultrasonic Machining of Ceramics

In ultrasonic machining, ultrasonic vibration is given to the machining tool. Then the machining tool is pressed to the workpiece at a constant load. Abrasive-grain-containing slurry is supplied to a small gap formed between the tool and workpiece. Thus, brittle fractures are accumulated while abrasive grains are being injected with impact into the workpiece and the tool shape is transcribed into the workpiece. Figure 1 shows an outline of this machining method.[3] In this machining method, the machining rate per abrasive grain impact is extremely small. The number of impacts per unit hour, however, is large and fully practical machining speeds can be obtained. This machining method also involves brittle fracture and is best suited to machining ceramics materials whose tensile strength is small. In addition, the crushing rate per impact by abrasive grains is extremely small. This permits satisfactory machining accuracy and machined surface roughness to be obtained. This machining method does not result in large deteriorated layers (remaining cracks and machining distortions). Table 2 shows the machining properties of various types of ceramics materials.[4]

Table 2. Machining Properties[4]

Material	Abrasive grain	Machining speed (mm/min)	Machining ratio	Machining pressure (g/mm^2)
Glass	SiC #320	6.0	150-250	30-50
Barium titanate	SiC #320	6.5	70-110	100
Ferrite	SiC #320	6.5	90-130	80-150
Porcelain	SiC #320	6.5	200-240	30-50
Silica glass	SiC #320	5.5	100-140	80-150
Graphite	SiC #320	8.4	200-300	230
Silicon single crystal	SiC #320	3.5	200	230
Ruby	SiC #320	0.6	8-12	
Ruby	B_4C #280	0.8	5-7	

Table 2. Machining Properties[4] (Continued)

Material	Abrasive grain	Machining speed (mm/min)	Machining ratio	Machining pressure (g/mm^2)
Alumina	SiC #320	3.0	30-40	290
Alumina	B_4C #280	3.6	20-25	290
Cemented carbide G-2	B_4C #280	0.2	2.0	330
Cemented carbide type S	B_4C #280	0.3	4.0	330
Silicon nitride (HP)	B_4C #280	0.6	2.0	
Compax [phonetic] (artificial diamond sintered compact)	B_4C #280	0.17	0.014	
Silicon carbide	B_4C #280	0.7	2.3	
Zirconia	B_4C #280	0.4	1.3	
Machining conditions: Output 150 W, resonance frequency: 16 kHz, Tool: φ3 mm round bar (piano wire)				
Abrasive grain: SiC #320: Silicon carbide average particle size 48 μm; B_4C #280: Boron carbide average particle size 40 μm				
Machining ratio = machining depth/tool abrasion rate				

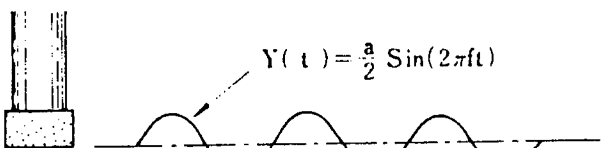


Figure 2. Movement of Abrasive Grain on Grindstone End Face[5]

The above is a typical example of ultrasonic machining, in which free abrasive grains are used as a machining medium. Various ceramics material machining methods using ultrasonic waves have already been developed. For example, the ultrasonic vibration-grinding machining[5] can be cited. In this machining method, highly efficient drilling is carried out by giving ultrasonic vibration and rotation to a sintered grindstone or electrodeposition diamond grindstone. Examples of machining using the above method are shown in Figures 2 and 3, respectively. Further, an example[6] of a lowering in the grinding resistance arising from the application of ultrasonic waves, is shown in Figure 4.

Laser-Beam Machining of Ceramics[7]

In laser-beam machining, laser beams are converted on the workpiece surface to thermal energy having a high power density in order to remove materials. This method is not liable to be affected by the hardness of materials, compared with general machining, and can readily process hard, brittle materials such as ceramics. Figure 5 shows the basic structure of a laser-beam machining unit and machining conditions and factors. As shown in Figure 5, laser-beam machining is characterized by non-contact machining using an optical system and has the following features:

a) Precise machining position control;

b) No changes in tools (abrasion, etc.) due to passage of time, thus ensuring stable machining;

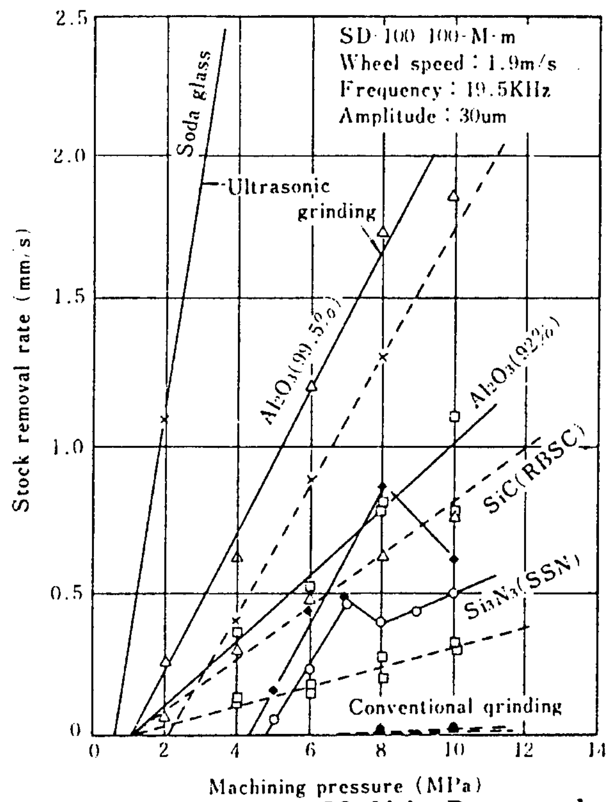


Figure 3. Relation Between Machining Pressure and Removal Rate of Various Ceramics[5]

c) Changing the power density to a wide range permits several machinings, such as drilling, cutting, heat treatment, etc., to be carried out.

As an example of laser-beam machining, the drilling of a preliminary hole in a diamond die is well known. Tables 3 and 4 give examples of laser-beam drilling and cutting of various types of ceramic materials.

Table 3. Ceramics Laser Drilling[7]

Parts/material	Thickness (mm)	Bore diameter (mm)	Laser used	Laser output	No. of pulse	Time (sec)
Diamond die	1	0.05	YAG	0.5-1.0J	equivalentto20	2
Ruby bearing	0.3	0.06	YAG	40kWQswitch	40	0.1
Ferrite	1	0.1	YAG	0.5-1.0J	equivalentto10	1
Alumina ceramics	3	0.2	YAG	1-2J	equivalentto50	5
Alumina ceramics	3.2	0.25	Ruby	1.4J	equivalentto40	8
Alumina ceramics	0.6	0.5	CO_2	75W		0.2
Alumina ceramics	0.7	0.25	CO_2	250W		1
Fused quartz block	3	0.2	CO_2	60W		3
Fused quartz block	5.8	1.6	CO_2	100W		3

Machining conditions:
Sample: LXA (alumina manufactured by Toshiba Tungaloy Co., Ltd.)
Frequency: 21 kHz
Tool amplitude: 25 μm (p-p), 0 μm (p-p)
Coolant pressure: 3 kgf/cm^2G
Machining depth: 2 mm each
Machining speed: 4 mm/min

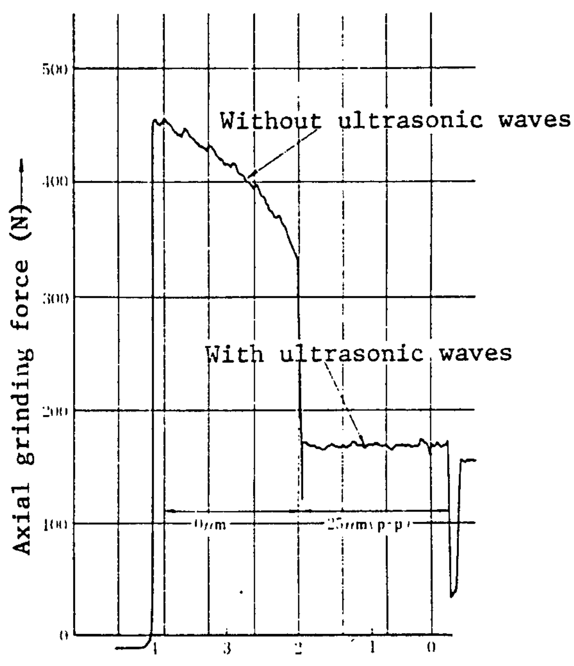


Figure 4. Lowering of Grinding Force Due to Ultrasonic Waves[6]

Table 4. Cutting of Ceramics Using CO_2 Laser[7]

Material	Thickness (mm)	Cutting speed (m/min)	Cutting width (mm)	Laser power (kW)	Auxiliary gas
Alumina	1.4	0.76	0.4	0.2	N_2
Alumina	0.4	1.3	0.3	0.25	N_2
Alumina	0.8	0.02	—	0.25	None
Alumina	0.6	2.3	—	0.5	—
Fused quartz block	1	2.5	—	0.5	Air
Fused quartz block	9.5	0.13	—	1.0	—
Silica glass	1.9	0.6	0.2	0.3	—
Pyrex glass	2.2	0.5	—	0.3	—
Glass	9.52	1.52	1.0	20	None
Micalex	3	0.4	—	0.35	None
Tile	6.4	0.5	—	0.85	—
Concrete	38	0.13	—	8	None
Asbestos	3	1	—	0.35	Air

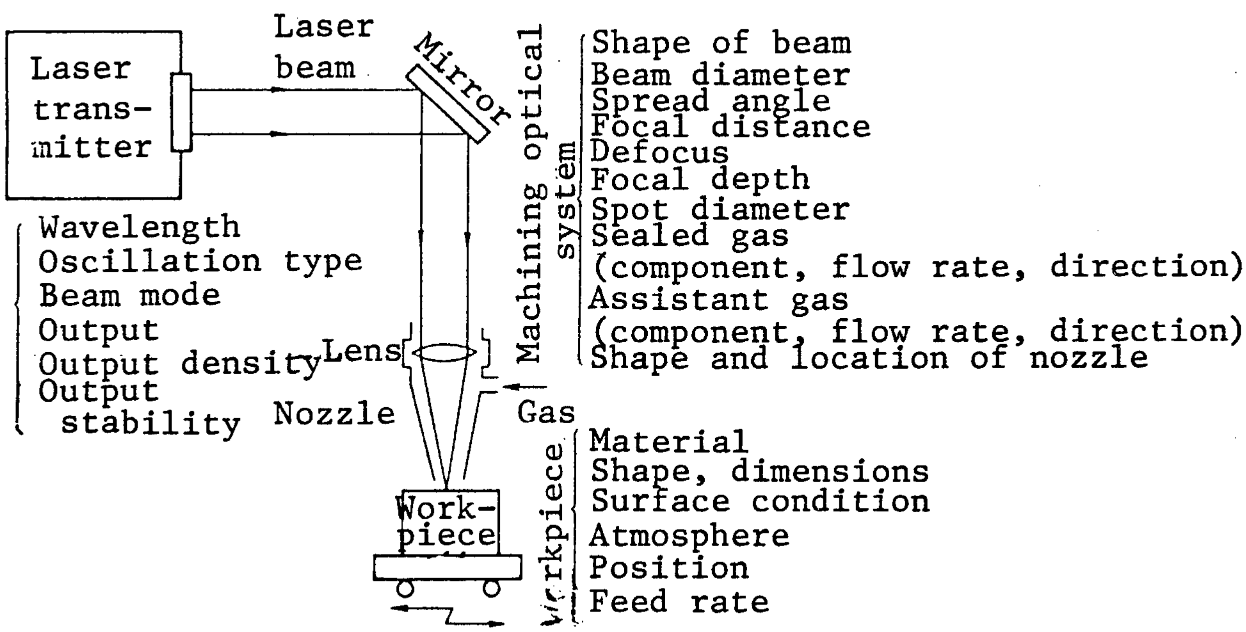


Figure 5. Basic Structure and Condition Factors of Laser-Processing Machine[7]

4. Electric-Spark Machining of Ceramics

Here, emphasis is laid on the examples of ceramics materials which can be machined by electric sparks.

4-1 Development of Conductive Ceramics[8]

Of the typical fine ceramics, ceramics materials such as Si_3N_4, Al_2O_3, ZrO_2, sialon (except SiC) are insulating materials and cannot be machined by electric sparks. To give conductivity to the above ceramics materials utilizing their heat-resistance and abrasion-resistance properties, it is necessary to uniformly and stably disperse a conductivity-giving agent into the ceramics materials, which are sintered at high temperatures. To this end, it is important to select as a conductivity-giving agent any hard material which is not liable to decompose and react during the sintering of ceramics. We selected TiN as a conductive grain and dispersed it into Si_3N_4. Thus, Si_3N_4 material having superior conductivity (hereinafter referred to as EDM-Si_3N_4) has been developed.

Where conductive grains (TiN) uniformly disperse in an insulating base material (Si_3N_4), provided the law of

mixture is followed, electric conductivity can be represented by formula (1) below, with respect to the conductivity-giving mechanism of EDM-Si_3N_4.[9]

$$K_c = K_m \frac{K_d + 2K_m - 2V_d (K_m - K_d)}{K_d + 2K_m + V_d (K_m - K_d)}$$

approximately or equal to

$$K_m \frac{1 + 2V_d}{1 + V_d} \quad (K_m < K_d) \quad (1)$$

where Kc = composite material, Km = base material, Kd = electric conductivity of dispersed grains, Vd = volume percentage of dispersed grains.

Meanwhile, supposing that all conductive grains form a network in a three-dimensional manner, formula (2) below can be established approximately.

$$K_c = \tfrac{1}{3} V_d \times K_d \quad (2)$$

Electric conductivity actually measured when the TiN grain-addition rate for EDM-Si_3N_4 was changed and the results of calculations based on formulas (1) and (2), can be expressed as per Figure 6. The figure shows that as the TiN addition rate increases, actually measured values become close to the values calculated using formula (2). It is presumed that in the region where the TiN addition rate is comparatively high, a network by TiN grains is formed. Meanwhile, as shown in Figure 7, even if the TiN addition rate remains constant, the electric conductivity lowers with an increase in the TiN grain size. This appears to be caused by a decrease in the probability of contact between TiN grains as the TiN grain size increases. In other words, it is presumed that the conductivity-giving agent uniformly disperses into grain boundaries of the Si_3N_4 sintered compact. Furthermore, some of the conductivity-giving agent reacts with Si_3N_4 grain surface layers and grain boundaries and forms an intergranular network having three-dimensional high electric conductivity.

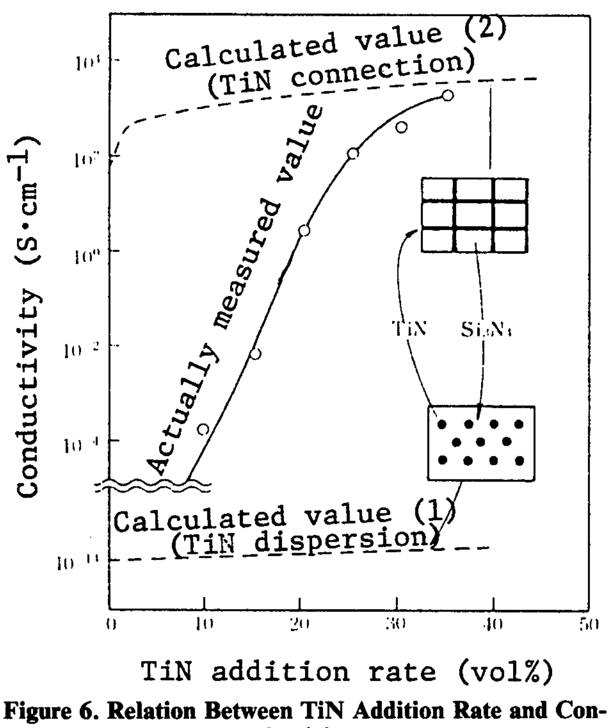


Figure 6. Relation Between TiN Addition Rate and Conductivity

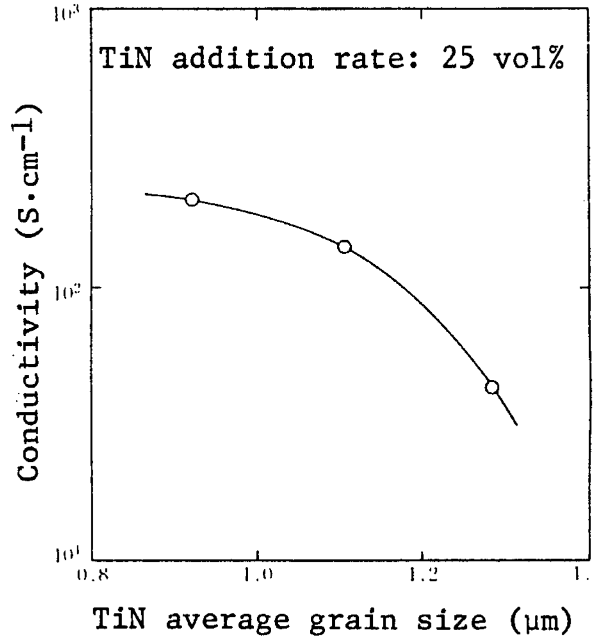


Figure 7. Relation Between Conductivity and TiN Average Grain Size

Meanwhile, as the TiN addition rate increases, the change in bending strength decreases and hardness increases as shown in Figure 8. Since TiN is harder than Si_3N_4, the hardness of the material appears to be enhanced by increasing the amount of TiN.

4-2 Properties of Wire-Cut Electric-Spark Machining[10]

The electric-spark machining properties of EDM-Si_3N_4 have a strong correlation with electric conductivity. Figure 9 shows the results of wire-cut electric-spark machining of EDM-Si_3N_4 under the same conditions. The figure shows that an electric conductivity of 10^2s x cm^{-1} is the lower limit allowing satisfactory electric-spark machining.

Figure 10 [not reproduced] shows the results of observation (using a scanning type electric microscope) of surfaces machined by electric sparks. The comparison of the cemented carbide with EDM-Si_3N_4 machined respectively by wire-cut electric sparks shows that molten substance adheres to the cemented carbide but that not much molten substance adheres to EDM-Si_3N_4 and grain shapes can be observed. In the wire-cut electric-spark machining of cemented carbide and steels, there are many portions which are machined by the melting of metals. It is presumed, however, that in the case of EDM-Si_3N_4, machining by the decomposition and sublimation of Si_3N_4 and TiN is added.

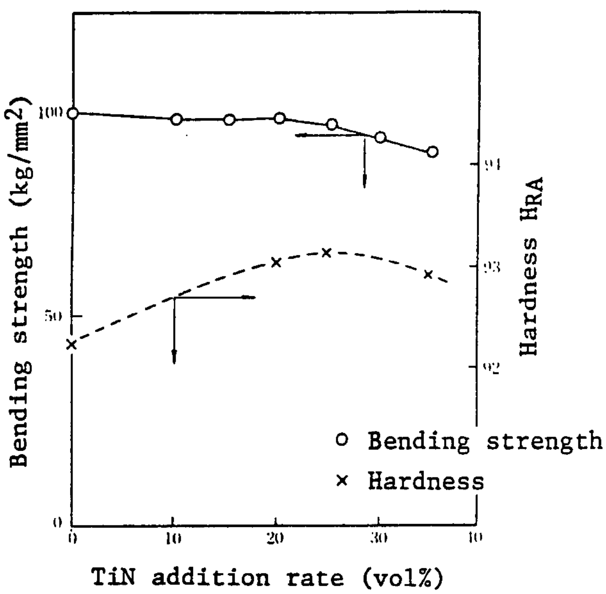


Figure 8. Relation Between Mechanical Properties and TiN Addition Rate

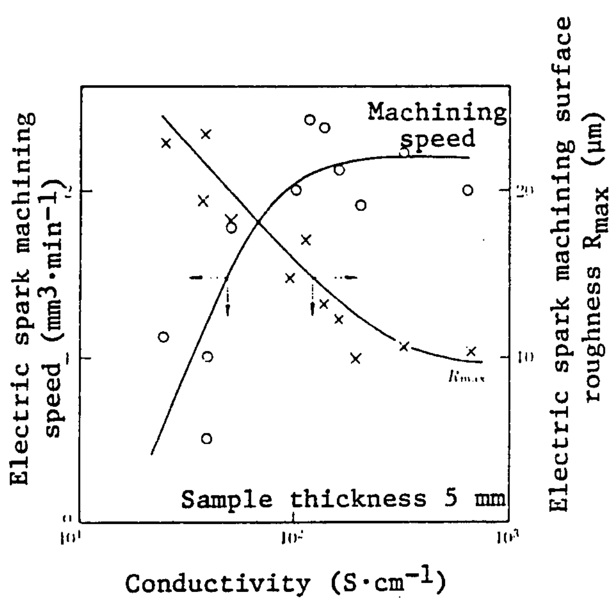


Figure 9. Relation Between EDM-Si_3N_4 Conductivity and Electric Spark Machining Properties

Figure 11 shows the results of a comparison of volume machining speeds with the roughness of finished surfaces when various types of conductive ceramics were processed by wire-cut electric sparks.[2] It can be said that satisfactorily processed surfaces can be obtained in large machining speed regions in regard to Si_3N_4 group ceramics.

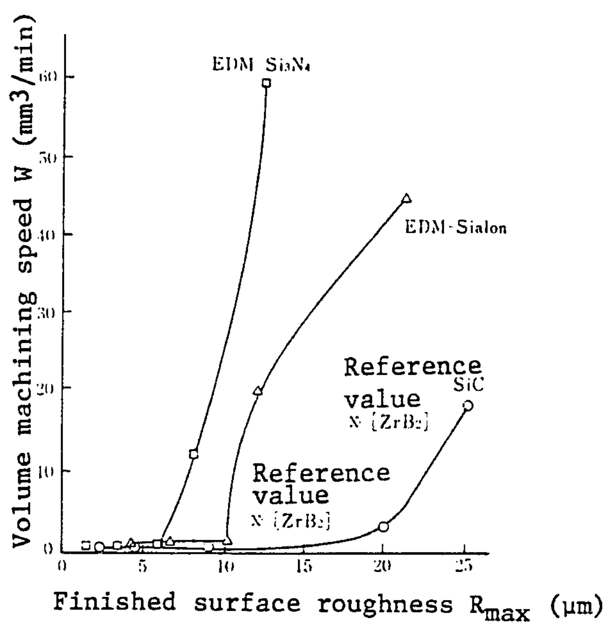


Figure 11. Relation Between Various Ceramics Volume Machining Speed and Finished Surface Roughness[2]

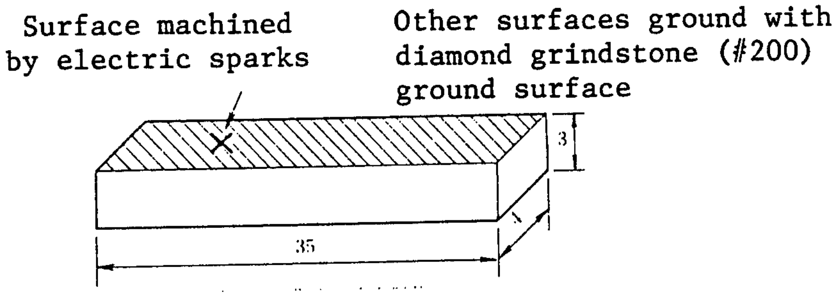
4-3 Surface Defects Due to Electric-Spark Machining[10]

In electric-spark machining, surface cracks arising from thermal shocks pose large problems. Therefore, in order to investigate the size of such surface cracks, a specimen shown in Figure 12(a) was prepared. Then, bending strength tests were conducted in such a way that tensile stress was applied to the surface machined by electric sparks at a peak current of 35A and a machining speed of 0.5 mm/min using a wire-cut electric-spark machine. Other surfaces were machined with a diamond grindstone. The bending strength of the ground surfaces was 87 kg/mm^2, whereas the bending strength of the surface machined by electric sparks lowered to 65 kg/mm^2. However, as the surface machined by electric sparks was ground, the bending strength was recovered as shown in Figure 12(b); the bending strength was almost recovered at a grinding removal rate of 30 μm. In other words, where ceramics materials are machined by electric sparks, surface defects are liable to be left after machining. It is considered, therefore, that final finish electric-spark machining should be carried out carefully.

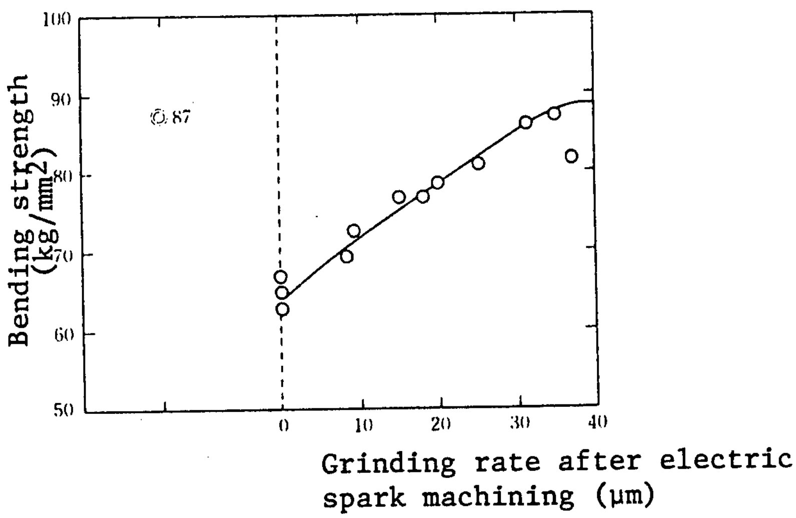
4-4 Examples of Electric-Spark Machining[10]

Figure 13 [not reproduced] shows an EDM-Si_3N_4 workpiece machined by electric sparks. Workpieces are machined to the required shape by wire-cut electric-spark machining and also are drilled by electric-spark machining using forms, thus permitting precision machine parts to be manufactured.

Figure 14 shows examples of microscopic drilling. A hole of 85 μm in minimum width was processed in an EDM-Si_3N_4 plate having a thickness of 0.6 mm. As a result, it has been revealed that it is possible to carry out

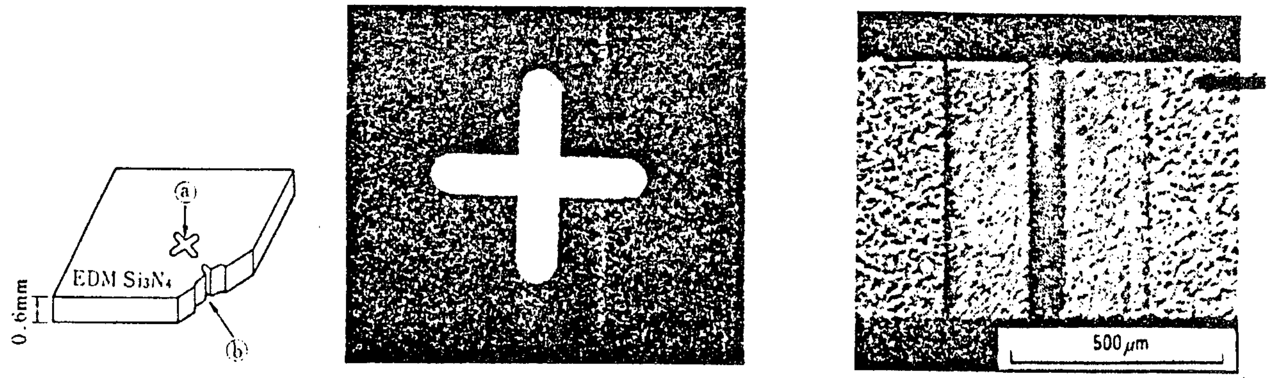


(a) Bending Test Specimen Surface Machined by Electric Sparks



(b) Results of Bending Test on Surface Machined by Electric Sparks

Figure 12. Effect of Electric Spark Machining on EDM-Si_3N_4



a) Upper surface of specimen

b) Cross section of specimen

Figure 14. Microscopic Drilling of EDM-Si_3N_4 (Toray Precision Co., Ltd.)

precision machining at a surface (machined by electric sparks) roughness of 3 μm in terms of R_{max}.

4-5 Electric-Spark Machining of Nonconducting Ceramics

It is not possible to machine nonconducting ceramics by electric sparks, but research is being carried out in regard to electric-spark machining of Al_2O_3 using an electrolytic-solution process.[11,12] In this process, submerged electric discharge is caused between the tool electrode and electrolytic solution to process the adjacent workpiece by melting, decomposition, and chemical reactions. It is expected that electric-spark machining using an electrolytic-solution method will be put into practical use in the future, though such a process involves low machining speed.

5. Conclusion

As special machining technology for ceramics, an outline of ultrasonic machining, electric-spark machining, and laser-beam machining has been described in this paper. It is most desirable that the required machining accuracy be achieved by sintered compacts. Conventional ceramics manufacturing and processing technology, however, cannot be applied to the machining of machine parts and electromagnetic parts without secondary processing. In view of material manufacturing, therefore, a manufacturing process capable of keeping machining cost as low as possible should be established. Also, in view of machining, a total machining technology ensuring highly efficient and low-cost machining should be established by selecting, combining, and compounding a wider range of machining techniques. Along with this, it is necessary to develop new materials with consideration given to good processibility as shown in EDM-Si_3N_4. It appears that the use of ceramics materials will be increasingly expanded and we hope that superior manufacturing and machining technologies will be developed.

References

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3. S. Ishiwata, "Industrial Material," Vol 33, No 6, 1985.

4. K. Nirei, "Machine and Tool," Vol 32, No 5, 1988.

5. K. Umino et al., Precision Machinery Academic Society Autumn General Meeting Lecture Thesis Collection (1985), p 123.

6. S. Ishiwata, "Ceramics Machining Handbook," Nikkan Kogyo Shinbunsha (1987) p 211.

7. N. Yasunaga, "Ceramics Machining Handbook," Nikkan Kogyo Shinbunsha (1987) p 241.

8. E. Kamijo et al., "Sumitomo Electric," Vol 125 (1985).

9. J. C. Maxwell, A Treatise on Electricity and Magnetism, Vol 1, Oxford (1904).

10. M. Miyake, "Ceramics," Vol 21, No 8 (1986) p 719.

11. Y. Inoue, "Electric Processing Technology," Vol 8, No 21 (1984).

12. Y. Kida et al., Precision Machinery Academic Society Autumn General Meeting Lecture Thesis Collection (1985) p 749.

Magnetic Material-Related Patent Applications Listed

43063819 Tokyo KAGAKU GIJUTSU in Japanese May 89 pp 31-38

[Survey by Yuki Shirakawa, Tohoku University]

[Text]

I. Hard

1. Cobalt-Nickel Alloy Magnetic Thin Film
Page: 5
Applicant: Matsushita Electric Industrial Co., Ltd.
Publication in a Patent Gazette and its number: (1988)-501 (hereinafter referred to as "Publication")
Contents (Drafts): After forming by a vacuum oblique vapor-deposition technique, treatment in a water solution containing 0.02M/l borax and 0.1M/l boric acid at 30°C

2. Method for Manufacturing Unidirectional Silicon Steel Featuring a High Magnetic Flux Density and Low Iron Loss
Page: 8
Applicant: Kawasaki Steel Corp.
Publication: 1,372
Contents: Local processing of the surface before annealing for a finish; secondary recrystallization control; coating of a dilute water solution

3. Method for Manufacturing Unidirectional Silicon Steel Plate Featuring High Magnetic Flux Density and Low Iron Loss
Page: 6
Applicant: Kawasaki Steel Corp.
Publication: 1,373
Contents: Contains MgO as its main element; after an application of a coating of an annealing and separation agent, decarbonization is promoted and subdivisions are formed for lagging domains; this is followed by a primary recrystallization

4. Method for Forming Forsterite Insulating Film on Unidirectional Silicon Steel Sheets
Page: 12
Applicant: Nippon Steel Corp.
Publication: 3,007
Contents: Forming $MgO-SiO_2$ insulating film on the surface

5. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets Featuring High Magnetic-Flux Density
Page: 12
Applicant: Nippon Steel Corp.
Publication: 3,008
Contents: A slurry form of an annealing and separation agent containing MgO as its main element is coated as an under coat; followed by a finish annealing after an application of an electrostatic coating; heating at high temperature and ordinary steel products

6. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets Featuring Good Forsterite Coating
Page: 11
Applicant: Nippon Steel Corp.
Publication: 3,009
Contents: Adjustment of O_2 partial pressure in the annealing atmosphere for a finish; retaining temperature; time setting; is especially effective for use as a high-activity material rich in Mn

7. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Excellent Magnetic and Coating Properties
Page: 6
Applicant: Nippon Steel Corp.
Publication: 3,022
Contents: Chloride additives Sb_2, $Sb_2(SO_4)_3$(Sb, Sr, Ti, Zn) are added to MgO annealing and separation agent

8. Annealing and Separation Material for Unidirectional Silicon Steel Sheets
Page: 3
Applicant: Nippon Steel Corp.
Publication: 3,025
Contents: Contains 2 to 15 W/o Si_3Ni_4 in addition to MgO; features an excellent external appearance and adhesivity

9. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets Featuring Excellent Magnetic Properties
Page: 9
Applicant: Nippon Steel Corp.
Publication: 5,454
Contents: The surface and the center have different C densities; a two-stage heat treatment; the surface grain size > 17 µm

10. Method of Introducing Deformations Into Grain-Oriented Electromagnetic Steel Strips for Improving Their Iron Loss
Page: 6
Applicant: Nippon Steel Corp.
Publication: 6,610
Contents: By introducing dislocations by mechanical and thermal means, the magnetic domains are further subdivided into narrower widths to improve iron loss

11. Method for Processing Grain-Oriented Electromagnetic Sheets
Page: 6
Applicant: Nippon Steel Corp.
Publication: 6,611
Contents: No drop in iron loss properties after annealing for distortion removal

12. Method for Manufacturing Ferromagnetic Iron Oxide Containing Cobalt
Page: 4
Applicant: Ishihara Sangyo Kaisha Ltd.
Publication: 9,734
Contents: For use as a magnetic recording medium; Br/Bm = 0.848, thermal characteristics Tp = Hc (125/15°C) = 81

13. Method for Manufacturing Unidirectional Electromagnetic Thin Steel Sheets Having High Magnetic-Flux Density That Feature Low Iron Loss
Page: 10
Applicant: Nippon Steel Corp.
Publication: 11,406
Contents: Cold-rolling thickness restraint (final), 0.15-0.25 mm

14. Method for Manufacturing Unidirectional Electromagnetic Sheets Having High Magnetic-Flux Density That Feature Excellent Magnetic Properties
Page: 7
Applicant: Nippon Steel Corp.
Publication: 11,407
Contents: Si-Mn, (S, Se), Al, Ni, Sn, Su, Ti-Fe B_{100} = 1.95T, $W_{19/50}$ = 0.97 W/kg

15. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Excellent Magnetic Properties
Page: 9
Applicant: Nippon Steel Corp.
Publication: 11,408
Contents: C, Si, Mn, Cu (S, Se)-Fe, annealing temperature and retaining time are controlled in the former and the latter half, $W_{15/50}$ = 0.70 W/kg, $W_{17/50}$ = 1.03 W/kg

16. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets Featuring Excellent Magnetic Properties
Page: 8
Applicant: Nippon Steel Corp.
Publication: 15,967
Contents: The oxygen content of a steel sheet after decarbonization and annealing depends on its thickness

17. Method for Manufacturing Non-Oriented Electromagnetic Steel Sheets Featuring Excellent Magnetic Properties
Page: 6
Applicant: Nippon Steel Corp.
Publication: 16,445
Contents: JIS grade S8, annealing heating temperature and retaining time adjusted

18. Method for Manufacturing Non-Oriented Electromagnetic Sheets Featuring Strong Resistance to Brittleness and Excellent Magnetic Properties After Annealing for Distortion Removal
Page: 4
Applicant: Nippon Steel Corp.
Publication: 16,446
Contents: Semi-process material; 430 W/kg, B_{50} = 1.73T; repeated bending = 45 times

19. Method for Manufacturing Non-Oriented Electromagnetic Sheets Featuring Strong Resistance to Brittleness and Excellent Magnetic Properties After Annealing for Distortion Removal
Page: 5
Applicant: Nippon Steel Corp.
Publication: 16,447
Contents: The post-winding annealing process is omitted

20. Method for Manufacturing Magnetic Metal Powder
Page: 4
Applicant: Ube Industries, Ltd.
Publication: 17,886
Contents: Metal Fe powder containing Ni; grain macrodome = 0.05-0.5 μm

21. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Ultralow Loss
Page: 6
Applicant: Nippon Steel Corp.
Publication: 19,567
Contents: Imparting of distortions; magnetic domains being subdivided still further; $W_{17/50}$ = 0.70 W/kg

22. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Excellent Magnetic Properties
Page: 4
Applicant: Nippon Steel Corp.
Publication: 19,568
Contents: The surface coating is removed at intervals; SV plating; 0.75 W/kg after distortion removal

23. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets
Page: 4
Applicant: Nippon Steel Corp.
Publication: 19,570
Contents: Heating is obtained by using the slab itself as the resistor and by adjusting the current density by the electrode-pressing pressure

24. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Highly Excellent Magnetic Properties
Page: 6
Applicant: Nippon Steel Corp.
Publication: 19,572
Contents: After removing the surface coating at intervals, coatings of Sb, Cu, Sn, Zn, Ni, Cr, and Mo are applied; 0.67 W/kg

25. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Extremely Excellent Magnetic Properties
Page: 7
Applicant: Nippon Steel Corp.
Publication: 19,573
Contents: Application of insulating coating; annealing for distortion removal; loss 0.74 W/kg (before treatment: 0.94)

26. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Good Surface Shape and Extremely Low Iron Loss
Page: 6
Applicant: Nippon Steel Corp.
Publication: 19,574
Contents: Distortion-imparting method; heat-resistant magnetic domains are subdivided still further; 0.70 W/kg (before treatment: 0.84)

27. Method for Manufacturing Grain-Oriented Electromagnetic Steel Sheets Featuring Extremely Low Iron Loss
Page: 7
Applicant: Nippon Steel Corp.
Publication: 19,575

Contents: The insulating coating is removed; pickling; metal plating with Sb, Zn, Sn and Ni; 0.76 W/kg (before treatment: 0.91)

28. Powders for Powder Metallurgy for Manufacturing Soft Magnetic Parts
Page: 5
Applicant: Nippon Steel Corp.
Publication: 23,241
Contents: P-Fe, Hc = 0.73 Oe

29. Non-Oriented Electromagnetic Steel Sheet Featuring Low Iron Loss and Excellent Magnetic Flux Density and Its Manufacturing Method
Page: 5
Applicant: Nippon Steel Corp.
Publication: 23,262
Contents: 2.64 W/kg, B_{50} = 1.77T

30. Method for Manufacturing Unidirectional Electromagnetic Steel Sheets Featuring Excellent Magnetic Properties
Page: 12
Applicant: Nippon Steel Corp.
Publication: 24,046
Contents: Application of ceramic coating containing mainly Mg_2SiO_4; Bs greater than or equal to 1.9T

31. Magnetic Recording Medium
Page: 6
Applicant: TDK
Publication: 25,687
Contents: Cu-Ni-(Co, Fe), 5, 1kG, 760 Oe, Br/Bs = 0.97

32. Magnetic Recording Medium
Page: 6
Applicant: TDK
Publication: 25,688
Contents: Cu-Ni-(Fe, Co)-Mn; "spinordal" dissolution; small losses in the quantity of magnetism in magnetic cards

33. Grain-Oriented Electromagnetic Steel Sheet Featuring Low Iron Loss and Its Manufacturing Method
Page: 5
Applicant: Nippon Steel Corp.
Publication: 30,968
Contents: Magnetic domains subdivided still further; coatings of Al, Si, Sb, Cu, Sn, Cr, Mn and B oxides applied

34. Method for Manufacturing Magnetic Powder for Magnetic Recording
Page: 3
Applicant: Hitachi Maxell, Ltd.
Publication: 31,085
Contents: Oxidized Fe containing Co; 570 Oe, 1,703 G, Br/Bs = 0.835; ratio of orientation = 2.50

35. Method for Manufacturing Magnetic Powder for Magnetic Recording
Page: 3
Applicant: Hitachi Maxell, Ltd.
Publication: 31,086
Contents: A shearing stress is applied mechanically; 560 Oe; 1,796 G, Br/Bs = 0.861; ratio of orientation = 3.02

36. Material for Magnetic Head Core
Page: 3
Applicant: Toshiba Corp.
Publication: 31,087
Contents: Ni-Mo, W, C, Nb, Ta, Ti, Cu, Co, Si, Mn and Al cladding in more than two layers: μe = 1,550 (3 layers)

37. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Extremely High Magnetic-Flux Density and Low Iron Loss
Page: 8
Applicant: Kawasaki Steel Corp.
Publication: 31,528
Contents: Decarbonization and adjustment; control of the application and processing of the coating liquid; B_{10} = 1.92T, $W_{17/50}$ = 0.78 W/kg

38. Method for Manufacturing Extremely Thin Grain-Oriented Silicon Steel Sheets Featuring Excellent Magnetic Properties
Page: 5
Applicant: Kawasaki Steel Corp.
Publication: 31,529
Contents: Contact, bend and stretch rolling and no intermediate annealing; good orientation

39. Method for Manufacturing Silicon Steel
Page: 3
Applicant: The United States
Publication: 32,851
Contents: C, Mn, S, B, Al, Ni, Cu, Si = 2.5-4.0; three-dimensional orientation; $\mu_{10} > 1,870$

40. Method for Manufacturing Magnetic Recording Medium
Page: 6
Applicant: TDK
Publication: 33,285
Contents: Cu-Ni-Fe-Co; thin sheets of an alloy with a thickness of less than 1 mm when freeze-solidified

41. Magnetic Recording Medium
Page: 4
Applicant: TDK
Publication: 33,286
Contents: Thin metal film containing Co, Sb; features mechanical strength and corrosion resistance

42. Magnetic Recording Medium
Page: 4
Applicant: TDK
Publication: 33,287
Contents: Contains Co and Bi; excellent S/N ratio

43. Method for Manufacturing Metallic Magnetic Powder for Magnetic Recording
Page: 8
Applicant: Tone Sangyo Co. and Furukawa Co., Ltd.
Publication: 34,605

Contents: Doped Mg and Cr enter the crystal grains of oxyhydroxide Fe, and a difference arises in the density between the center and surface

44. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Thermal Stability and Ultralow Iron Loss
Page: 10
Applicant: Kawasaki Steel Corp.
Publication: 35,684
Contents: After annealing for the final finish, an extremely thin tension film of Ti and Zr under -C and -N is formed by CVD; features good thermal stability; 0.72 W/kg

45. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Extremely Low Iron Loss
Page: 12
Applicant: Kawasaki Steel Corp.
Publication: 35,685
Contents: Varying the components of different kinds of ultrathin tension coatings into two to four layers

46. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Ultralow Iron Loss
Page: 12
Applicant: Kawasaki Steel Corp.
Publication: 35,686
Contents: Subdivision and adjustment of ultrathin tension coatings; 0.67 W/kg

47. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Ultralow Iron Loss
Page: 9
Applicant: Kawasaki Steel Corp.
Publication: 35,687
Contents: CVD at above 500°C; 0.60 W/kg

48. Method for Manufacturing Unidirectional Silicon Steel Sheets Featuring Ultralow Iron Loss
Page: 6
Applicant: Nippon Steel Corp.
Publication: 44,804
Contents: Formation of grooves with a depth $> 5\ \mu m$; point or broken-line-shaped magnetic domain control; no deterioration in properties after annealing for distortion removal

49. Method for Manufacturing Thick Steel Plates for Use as Structural Materials That Feature High Permeability
Page: 8
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 45,442
Contents: Steel containing C, Mn, P, S, Al, N, O, Nb, V, and Ti; $\mu m > 1{,}000$; $B_{H-54\ A/m} > 1.6T$; iron core, magnetic shield

50. Method for Manufacturing Hot-Rolled Iron Sheets Featuring High Permeability
Page: 8
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 45,443
Contents: $\mu m > 4{,}000$, $B_{50\ Oe} > 1.35T$; annealing at a temperature of between 800 and 900°C after cooling

51. Method for Manufacturing Unidirectional Electromagnetic Sheets Featuring Excellent Magnetic Properties
Page: 10
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 45,444
Contents: Control of the annealing and cooling process; retention of a pass at 5-500°C > 1 minute; $W_{17/50} = 0.81$ W/kg

52. Method for Applying Finish Annealing to Grain-Oriented Electromagnetic Steel Sheets
Page: 4
Applicant: Nippon Steel Corp.
Publication: 46,129
Contents: The finish annealing is applied by using a burner installed inside the furnace casing covering the inner cover

53. Method for Manufacturing Magnetic Materials
Page: 6
Applicant: Yamaha Motor Co., Ltd.
Publication: 46,962
Contents: Fe-Al-Si + elements of the platinum group + Ga, Ir high-density sintered body; 99.5 percent

54. Ferromagnetic Iron Core
Page: 3
Applicant: USSR
Publication: 47,131
Contents: For use in cylindrical wound-rotor induction equipment; a stack of equilateral tetragons; regulation of angle

55. Method for Manufacturing Unidirectional Silicon Steel Sheets
Page: 12
Applicant: Kawasaki Steel Corp.
Publication: 52,086
Contents: Applying (Sn, Sb, Pb, B) (S, Se, Te, Sb) onto the steel surface prior to decarbonization

56. Magnetic Alloy Featuring High Permeability
Page: 3
Applicant: Hitachi Metals, Ltd.
Publication: 53,256
Contents: Contains Fe-Co-V-Si-Mn-Al-Zr-Ti and features high abrasion resistance and good vibration-proof properties

57. Method for Manufacturing Thin Sheets of an Alloy Featuring High Permeability
Page: 5
Applicant: Pioneer Electronic Corp.
Publication: 58,361
Contents: Magnetic recording head material; Co-Si-Fe-(V, Nb, Cr, Mo, W, Cu, Ce, Ni, Mn, Sn, Sb, Be)

58. Method for Manufacturing Dust Cores of an Iron-Silicon-Aluminum System Alloy

Page: 5
Applicant: Tohoku Metal Industries, Ltd.
Publication: 60,081
Contents: Primary and secondary burning under a non-oxidizing atmosphere

59. Method for Manufacturing Non-Oriented Electromagnetic Steel Sheets Featuring Excellent Iron Loss Feature
Page: 4
Applicant: Nippon Steel Corp.
Publication: 61,370
Contents: Full process cold rolling; after a mixed solution containing Al and Cr Na-phosphate is applied, annealing is had for a finish; $W_{15/50} = 1.84$ W/kg

60. Ferromagnetic Alloy
Page: 10
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 65,712
Contents: Fe-B-(Nd, Pr) (Dy, Ho, Tb, Ca, Ce, Cd, Y) 8.2 kOe, 13.4 kG, 41.6 MG x Oe (Fe_{79} B_7 Nd_{14})

61. Method for Manufacturing Compound Magnetic Material Featuring a Compound Magnetization Curve
Page: 4
Applicant: Hitachi Metals, Ltd.
Publication: 66,888
Contents: A sintered body of two kinds of Fe alloys with differing Hc; hot working, plastic working, alloying only in the boundaries

62. Magnetic Recording Medium
Page: 3
Applicant: TDK
Publication: 67,325
Contents: A continuous thin film of Co-(Zn, Ir); thickness of the vertically magnetized film 500 - 3 μm; a two-layer structure, increased recording density

63. Vertical Magnetic Recording Medium
Page: 7
Applicant: Teijin Limited
Publication: 67,326
Contents: Co-Cr(Re-W-Mo)

64. Method for Manufacturing Vertical Magnetic Film
Page: 8
Applicant: Teijin Limited
Publication: 67,328
Contents: The neighborhood of the target for spattering is supplemented with plasmas to raise the density

65. Method for Manufacturing Needle-Shaped α-FeOOH for Use as Magnetic Recording Material
Page: 4
Applicant: Ishihara Sangyo Kaisha, Ltd.
Publication: 9,735
Contents: Ferrous salt solution → phosphite alkali neutralization; to pulverize into fine grains; needle-like; L/W = 13-14

66. Magnetic Recorder
Page: 4
Applicant: Toshiba Corp.
Publication: 11,762
Contents: (Bo, Sr, Ca, Pb) $(Zn, Ni, Cu, Fe, Mn)_2$ Fe_{16} O_{27} Co substitution, 0.01 - 0.3 μ, hexagonal crystal, c axis and perpendicular plane

67. Method for Manufacturing Sheetlike Ba Ferrite Particle Powder for Magnetic Recording Use
Page: 4
Applicants: Toda Kogyo Co. and SEIKAI KAKEN
Publication: 11,763
Contents: αFeO (OH), surface area 2 - 4 m^2/g; 42 - 47 emu/g; Hc 600 - 800 Oe

68. Needlelike Crystal-Structured Ferroalloy Magnetic Particle Powder for Magnetic Recording and Its Manufacturing Method
Page: 24
Applicant: Toda Kogyo Co., Ltd.
Publication: 14,484
Contents: αFeOOH containing Si, Cr, Ni, Mg, and P; α-Fe_2O_3; for video use

69. Method for Manufacturing Grains for Magnetic Recording Medium
Page: 6
Applicant: Tohoku Metal Industries, Ltd.
Publication: 31,924
Contents: (Ba, Sr, Ca)-$(Fe\text{-}Cu\text{-}Zn, Cd, Ni, Mn, Mg)_2$ Fe_{16} O_{27}, ${}_iH_c > 600$ Oe, $\sigma s > 60$

70. Method for Manufacturing Oxide Magnetic Core
Page: 3
Applicant: TDK
Publication: 31,925
Contents: MgO-MnO-ZnO-FeO_3, heating treatment temperature < 410°C, a light bulb type discharge lamp light source

71. Method for Manufacturing Oxide Magnetic Core
Page: 3
Applicant: TDK
Publication: 31,926
Contents: NiO, MnO, ZnO, Fe_2O_3 ferrite, heating treatment temperature < 430°C, for use as the light source of a discharge lamp

72. Method for Manufacturing Oxide Magnetic Core
Page: 3
Applicant: TDK
Publication: 31,927
Contents: LiO, MnO, ZnO, Fe_2O_3; < 460°C; for use as a light source

73. Method for Manufacturing Needle-Shaped α-FeOOH for Use as Magnetic Recording Material
Page: 6
Applicant: Ishihara Sangyo Kaisha, Ltd.
Publication: 32,243
Contents: Control of the reaction temperature giving rise to nucleation in a ferrous salt solution; adjustment of pH during the process

74. Method for Manufacturing Needle-Shaped α-FeOOH for Use as Magnetic Recording Material
Page: 5
Applicant: Ishihara Sangyo Kaisha, Ltd.
Publication: 34,608
Contents: Specification of the temperature and time in a ferrous salt solution

75. Method for Manufacturing Powder of Grains of Magnetic Iron Oxides for Use as Magnetic Recording Medium
Page: 7
Applicant: Toda Kogyo Co., Ltd.
Publication: 34,609
Contents: The surfaces of grains of a domain magnetic iron oxide are coated with magnetite; features excellent erasure effect properties

76. Compound Magnetic Material
Page: 6
Applicant: Dainippon Ink & Chemicals, Inc.
Publication: 46,563
Contents: Magnetic powder containing nylon, hydroxyn-monocarboxylic acid amides, and amino-base organic compounds; features good shaping and processing properties

77. Method for Manufacturing Ferromagnetic Substances
Page: 6
Applicant: TDK
Publication: 46,961
Contents: Trivalent Fe compounds are subjected to an oxidation-reduction using BNaH $\rightarrow$ dehydration through heating

78. Monocrystal Ferrite
Page: 2
Applicants: Hitachi Metals, Ltd. and Hitachi, Ltd.
Publication: 46,963
Contents: Mn-Zn ferrite + SnO_2; features good magnetic "hud" performance

79. Method for Manufacturing Oxide Magnetic Film
Page: 3
Applicant: Matsushita Electric Industrial Co., Ltd.
Publication: 46,970
Contents: $\alpha Fe_2O_4 \rightarrow Fe_2O_4\text{-}\gamma Fe_2O_2$; is formed on the surface of a disk-like magnetic recording medium

80. Method for Manufacturing Metallic Magnetic Powder
Page: 4
Applicant: Kanto Denka Kogyo Co., Ltd.
Publication: 49,722
Contents: α, β, γ-FeOOH; water glass treatment; burning reduction

81. Method for Manufacturing Magnetic Metallic Powder for Magnetic Recording
Page: 5
Applicant: Kanto Denka Kogyo Co., Ltd.
Publication: 50,842
Contents: Ni compounds are added to Fe oxides with a long axis of 0.5 - 5 μm and a short axis of 0.02 - 0.5 μm; Hc = 550 - 900 Oe; Br = 90 - 170 emu/g

82. Method for Manufacturing Powder of Needle-Shaped Crystalline Metallic Magnetic Grains Having Metallic Iron as Their Main Constituent
Page: 8
Applicant: Toda Kogyo Co.
Publication: 54,041
Contents: Generation of magnetite coating; σs = 123 emu/g; Hc = 1,250 Oe; σs reduction rate 40 percent

83. Method for Manufacturing Metallic Magnetic Powder
Page: 6
Applicant: Hitachi Maxell, Ltd.
Publication: 54,762
Contents: Oxyhydration Fe; the surfaces of the grains of the powder are deposited with a coating of Al, followed by a coating of Si compounds; squareness ratio = 0.51

84. Method for Manufacturing Metallic Magnetic Powder
Page: 6
Applicant: Hitachi Maxell, Ltd.
Publication: 54,763
Contents: Simultaneous coating of Zn and Si compounds; squareness ratio = 0.50

85. Ferrite Magnetic Core
Page: 9
Applicant: TDK
Publication: 59,241
Contents: Mn-Zn-Ni-Mg-Li-Fe oxide; electric power loss minimum temperature (H = 700 Oe) > 150°C A_2 point > 250°C

86. Ferrite Magnetic Core
Page: 12
Applicant: TDK
Publication: 59,242
Contents: Rate of change in Pc with time < 30 percent; amounts of components adjusted

87. Magnetic Film for Magnetic Bubble Elements (Devices)
Page: 3
Applicant: Fujitsu, Ltd.
Publication: 46,969
Contents: Y, Sm, Er, Ca(Fe, Fe)Om; anti-cracking of magnetic film

88. Magnetic Film for Magnetic Bubble Elements (Devices)
Page: 3
Applicant: Fujitsu, Ltd.
Publication: 67,327
Contents: Si containing Ca-Ge, Sm, Ru, and Y-Fe garnet

89. Amorphous Magnetic Alloy
Page: 4

Applicants: Masumoto, Fukamichi, Seiko Instruments, and Electronics, Ltd.
Publication: 4,625
Contents: Fe-M(B, Si, Ge)-N (Rh, Os, Ir, Pt) + Co 17, 1 kG, A_2 = 530°C

90. Carbon-Base Amorphous Ferroalloy Featuring High Permeability
Page: 5
Applicant: National Research Institute for Metals
Publication: 5,460
Contents: Fe-M(Cr Mo, W)-C; Bs = 7,700 G

91. Method for Manufacturing Amorphous Alloy
Page: 9
Applicant: Sony Corp.
Publication: 10,235
Contents: An electric current is introduced into a high-temperature plating bath; Co-P-Ni; σg = 111.6 emu/g; $\lambda = 4 \times 10^{-6}$

92. Amorphous Magnetic Alloy
Page: 5
Applicant: Matsushita Electric Industrial Co., Ltd.
Publication: 18,657
Contents: (Fe, Co, Ni) (Nb, Cu, Ti, Cr, Mo, W) B; ease of manufacturing; good mechanical properties

93. Method for Improving Iron Loss in Fe-Si-B System Amorphous Alloy Thin Strips
Page: 2
Applicant: Nippon Steel Corp.
Publication: 23,242
Contents: Distortion introduced; the annealing temperature is regulated by the crystallization temperature

94. Method for Improving Iron Loss in Fe-Si-B System Amorphous Alloy Thin Strips
Page: 2
Applicant: Nippon Steel Corp.
Publication: 23,243
Contents: Laser-beam irradiation; coils for power transformers; $W_{0.6/3000}$ = 7.0 W/kg; Jm = 70 K, Δ_{t60} = 70 K

95. Amorphous Ferroalloy With Improved Magnetic Properties and Its Manufacturing Method
Page: 5
Applicant: The United States
Publication: 30,393
Contents: Fe-B-Si-Cd; amorphous > 90 percent; Bo = 1.4T; B_{80} = 1.56T; Hc = 4.6 A/m

96. Amorphous Magnetic Alloy Material
Page: 9
Applicant: TDK
Publication: 31,535
Contents: (Fe, Co)-Pt group-(Si, B); magnetic head tape; small in tape loss arising from friction

97. Method for Manufacturing Amorphous Metallic Magnetic Material
Page: 6
Applicant: Hitachi Metals, Ltd.
Publication: 32,244
Contents: (Fe-Ni)MM; magnetization in the longitudinal and orthogonal directions of thin strips; improved high frequency characteristics

98. Magnetic Refrigerating Substance and Its Manufacturing Method
Page: 4
Applicant: National Research Institute for Metals
Publication: 35,702
Contents: (Gd, Dy, Er)-(Zr, Hf, Al, Si, Ge)-(Cu, Ni) amorphous; $Ge_{70} Ni_{10} Hf_{20}$: 0.13 $Jcm^{-3}K^{-1}$, 150 K, ΔT_{60} = 120 K

99. Magnetic Refrigerating Substance and Its Manufacturing Method
Page: 5
Applicant: National Research Institute for Metals
Publication: 35,703
Contents: Cu and Ag tapes complexed and integrated: 0.06 $Jm^{-3} K^{-1}$; λ = 1.0 $Wcm^{-1}K^{-1}$; ΔT_{60} = 70 K

100. Method for Manufacturing Amorphous Structures
Page: 3
Applicant: Toshiba Corp.
Publication: 46,121
Contents: A binder is added to amorphous powder, followed by heating and compaction

101. Method for Heat-Treating Amorphous Magnetic Alloy Material
Page: 9
Applicant: TDK
Publication: 58,221
Contents: (Fe, Co, Ni)-(transition elements other than Fe group)-(Zr, vitrifying elements); multiaxis magnetic anisotropy; A_2 point/crystallization temperature < heat treatment temperature

102. Amorphous Magnetic Alloy
Page: 4
Applicant: Matsushita Electric Industrial Co., Ltd.
Publication: 58,901
Contents: (Co, Fe) Mn Pd (Si, B), $\lambda s = 0$

103. Amorphous Alloy for Magnetic Heads
Page: 3
Applicant: Toshiba Corp.
Publication: 58,902
Contents: (Co-Fe-M) SiB, M = Ti, V, Cr, Mn, Ni, Zr, Nb Mo, W, Cu; excellent abrasion and corrosion resistance

104. High Magnetic-Flux Density Magnetic Core Material and Its Manufacturing Method
Page: 7
Applicants: DENJIKEN and MASUMOTOKEN
Publication: 62,579
Contents: B, C-Fe-Si amorphous; Bs > 16 kG; Hc = 9 Oe; $\mu m = 1.6 \times 10^6$; Hc = 9 Oe; annealing inside a magnetic field under pressure

105. Magnetic Resistance Effect Device
Page: 5

Applicant: NEC Corp.
Publication: 4,359
Contents: Is layered on top of a thin-film featuring a high permeability via an intervening non-magnetic layer

106. Laser-Based Equipment for Heat-Treating Ferromagnetic Sheets and Treatment Method
Page: 5
Applicant: WH
Publication: 15,968
Contents: The magnetic domain size is reduced by etching markings-off

II. Hard

1. Method for Manufacturing Fe-Cr-Co Magnetic Alloy Product
Page: 7
Applicant: WEC
Publication: 12,936
Contents: 12.7 kG, 570 Oe, 5 MG x Oe

2. Fe-Cr-Co System Compound Magnet and Its Manufacturing Method
Page: 3
Applicant: Tohoku Metal Industries, Ltd.
Publication: 31,922
Contents: "Spinordal" dissolution type; a soft steel mask is arranged; γ phase precipitation

3. Fe-Cr-Co System Magnet Featuring High Coercive Force
Page: 5
Applicant: Tohoku Metal Industries, Ltd.
Publication: 31,923
Contents: +W, Mo, Zr, Ti, Nb, V, Cu, Si, S, Al, Cu, MM, Hc = 1,300 Oe

4. Iron-Copper System Sintered Magnetic Core With High Coercive Force
Page: 4
Applicant: Hitachi Funmatsu (Powder) Co., Ltd.
Publication: 49,883
Contents: Fe-Cu-B, Br, Hc increases

5. Gold-Platinum-Cobalt System Permanent Magnet Alloy
Page: 7
Applicant: Citizen Watch Co., Ltd.
Publication: 52,102
Contents: Contains Fe, Ag, Cu and Pd; for use in making magnetic personal ornaments and magnetic health ornaments

6. Anisotropic Permanent Magnet
Page: 4
Applicant: Czechoslovakia
Publication: 59,243
Contents: Structure for raising the value of magnetic induction supplied inside an air gap

7. Method for Manufacturing Isotropic Barium Ferrite Sintered Magnet Featuring High Coercive Force $_iH_c$
Page: 5
Applicant: Toda Kogyo Co., Ltd.
Publication: 13,324
Contents: SiO_2, Al_2O_3 and MnO added; 2,350 G, $_iH_c$ = 4,240 Oe; 1.12 Mg x Oe

8. Method for Manufacturing Oxide Permanent Magnet
Page: 4
Applicant: Tohoku Metal Industries, Ltd.
Publication: 14,842
Contents: Improved electric resistance in hexagonal oxide permanent magnets; pulverization, boiling and cleaning; oxide Fe added after removing reactants

9. Method for Manufacturing Ferrite Magnet
Page: 3
Applicant: Hitachi Metals, Ltd.
Publication: 31,084
Contents: A mill scale of Fe is added with Ba and Sr carbonate and subjected to preliminary sintering; 4 kG, 2 kOe

10. Resin Magnetic Material
Page: 5
Applicant: Dainippon Ink & Chemicals, Inc.
Publication: 34,610
Contents: A mixture of two powders with different grain diameters and a synthetic resin; anisotropy

11. Method for Manufacturing Anisotropic Segment Magnet for Use in Electric Machines
Page: 6
Applicant: West Germany
Publication: 46,564
Contents: Sr-Ba ferrite; highest Br in the arc section; highest Hc in the edge section; its volume ratio is the ratio of Hc; DC motors with the smallest output-to-weight ratio

12. Method for Manufacturing Hard Ferrite Powder
Page: 9
Applicant: West Germany
Publication: 67,324
Contents: (Ba, Sr)0.6Fe_2O_2; saturation magnetization 6.62 mT cm^3/g; coercive force 428 kA/m

13. Method for Manufacturing Rare-Earth Magnet
Page: 2
Applicant: Seiko Instruments and Electronics, Ltd.
Publication: 502
Contents: Rapid quenching at 700-500°C after age hardening, followed by slow cooling at 150°-10°C/H

14. Method for Manufacturing Permanent Magnet
Page: 5
Applicant: Toshiba Corp.
Publication: 9,733
Contents: Co-Sm-Ti-Cu-Fe, 600 - 700°C x 0.1 - 2^h cooling < 5°C/minute; 30.0 MG x Oe

15. Method for Manufacturing Rare-Earth Cobalt Magnet
Page: 3

Applicant: Taiyo Yuden Co., Ltd.
Publication: 12,134
Contents: RCo_5 system alloy powder is immersed in an organic solvent; oxygen amount is adjusted; 11 kG, 8 kOe, 29.8 MG x Oe

16. Method for Manufacturing Oxide Permanent Magnet
Page: 4
Applicant: Tohoku Metal Industries, Ltd.
Publication: 14,842
Contents: Improving the electric resistance in hexagonal system oxide magnets; addition of oxide Fe after unreacted substances have been removed

17. Permanent Magnet Alloy Containing Rare-Earth Elements
Page: 7
Applicant: The Shin-Etsu Chemical Co., Ltd.
Publication: 26,187
Contents: Co-Sm-Fe-Cu-Ce 4.6 kOe, 16.8 MG x Oe

18. RCo_5 System Rare-Earth Cobalt Magnet and Its Manufacturing Method
Page: 4
Applicant: Taiyo Yuden Co., Ltd.
Publication: 34,604
Contents: Pr/Sm = 1.7-2.4

19. Method for Manufacturing Rare-Earth Cobalt System Permanent Magnet
Page: 4
Applicant: Sumitomo Special Metals Co., Ltd.
Publication: 34,606
Contents: R_2M_{17} type sintering; processing into a liquid form; adjusting the temperature range and speed in age hardening

20. Method for Manufacturing Rare-Earth Cobalt Magnet
Page: 4
Applicant: Tohoku Metal Industries, Ltd.
Publication: 34,607
Contents: R_2T_{17} type; processing into a liquid form; heat treatment under a high-pressure atmosphere prior to age hardening

21. Method for Manufacturing Rare-Earth Cobalt Magnet
Page: 6
Applicant: Tohoku Metal Industries, Ltd.
Publication: 58,898
Contents: R_2T_{17} type; R-Fe-Cu-Zr-Co; sintering; processing into a liquid form; limitations on the cooling speed

22. Method for Manufacturing Permanent Magnet Material
Page: 8
Applicant: Seiko Epson Corp.
Publication: 67,323
Contents: Sm-Fe-Cu-Zr-Co, Sm_2CO_7 type; an ingot is heat treated as it is, is pulverized and is added with a binder for mixed shaping; 28.5 MG x Oe

III. Others

1. Method for Manufacturing Nonmagnetic Rolls
Page: 5
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 64,489
Contents: C-Si-Al-Mn-Cr-Ni-Cu-N_2-V-Nb

2. Method for Manufacturing Nonmagnetic Rolls
Page: 5
Applicant: Sumitomo Metal Industries, Ltd.
Publication: 64,490
Contents: Reduction rate in hot rolling > 60 percent

3. Hexagonal Lattice Antiferromagnetic Invar Type Alloy and Its Manufacturing Method
Page: 6
Applicant: DENJIKEN
Publication: 3,942
Contents: Ge-Mn, α =-8 - 8 x 10^{-6}

4. Method for Manufacturing Magnetic Adhesive Sheets
Page: 4
Applicant: CI Kasei (C.I. Chemicals) Co., Ltd.
Publication: 6,128
Contents: Anisotropic magnetic powder; repulsion at the front and back of film

5. Magnetic-Resisting Elements and Their Manufacturing Method
Page: 6
Applicant: Matsushita Electric Industrial Co., Ltd.
Publication: 10,912
Contents: Deposition of Ni-Co on substrate (α = 95 - 170 x 10^{-7}); heat treatment in vacuum; $\Delta\rho/\Delta t$ = -1.000 ppm/°C

6. Amorphous Magnetic Material
Page: 3
Applicant: Hitachi Metals, Ltd.
Publication: 54,774
Contents: (Fe-Ni-Co)-Cr(Si, B, P, C), electromechanical coupling coefficient K = 0.81

Overview of Space Development Plan

90CF0008 Tokyo UCHU KAIHATSU KEIKAKU in Japanese 15 Mar 89 pp 1-27

[Text] On the Decision for a "Space Development Plan"

1. On 15 March 1989, the Space Development Committee finalized the "Space Development Plan," which is attached.

2. This plan shall define, along the "Space Development Policy Outlines," concrete development programs that have been proposed according to and approved by the government's budget plan. The Space Development Committee will draw up such a plan annually prior to each new fiscal year.

3. After the finalization of a new FY budget, the prime minister will, with the understanding of the above-mentioned "Space Development Plan," decide the "Basic Plan Concerning Space Development," which is the basis for concrete administration of related government businesses, in accordance with the finalized new fiscal budget.

Research and Development Bureau
Science and Technology Agency
Attachment:

Space Development Plan
15 March 1989
Space Development Committee

Preface

Today, the development and uses of artificial satellites have advanced in wide-ranging fields including communications, broadcasting, meteorological observations, earth observations, navigation assistance and scientific observations. In other words, space development has become indispensable in our daily lives. In recent years, with increasing expectation for space environmental applications, active research and development activities have been carried out worldwide, including in Japan.

In Japan, 40 artificial satellites have thus far been successfully launched and the development of the M rocket and the H-series rockets has advanced smoothly, almost as expected, in both scientific research and practical application. In September 1988, the communication satellite No 3-b "Sakura 3-b" was successfully launched by an H-I rocket, and in February 1989, No 12 science satellite "Akebono" was launched successfully with an M-3S II rocket. Furthermore, in September 1988, Japan, the United States, Europe and Canada signed the "Space Station Cooperation Agreement" concerning the space station plan, which is an international cooperative project. Thus, it can be said that Japan not only needs to promote diversified plans in both the areas of scientific research and practical uses, but also has arrived at a stage where it can contribute to global space development through these domestic plans.

Outside Japan, steady progress in space development has been made: the resumption of space shuttle flights by the United States, the successful launching of an Arian 4-type rocket by the European Space Agency, and the maiden flight for a USSR space shuttle, to name a few.

Based on the above-described worldwide situations, the progress of domestic R&D and the long-term prospect on space utilization, this "Space Development Plan" is to define concrete developmental programs according to the import of the Space Development Policy Outlines, which emphasize harmony between social needs and national power, the assurance of independence and harmony with other international activities.

To promote these development programs, several precious lessons acquired in past development experiences shall be remembered and concerned organizations in the industry, universities and government shall work in organic harmony.

Listed below are the main differences of this plan from the "Space Development Plan" (finalized on 11 March 1988):

1. The No 16 science satellite (NUSES-B) will be developed with the target launch date of FY93 by an M-3S II rocket.

2. The repeat experiment date for the space science experiment (SEPAC) using a particle accelerator is changed from FY90 to FY91.

3. A relay device capable of relaying disaster signals will be developed for the purpose of experimentation by loading the device on the geostatic meteorological satellite No 5 (GMS-5) .

4. Concerning the space station plan, the target year for launching Japan's space station-mounted experimental module (JEM) will be moved from FY95 to FY96.

Contents

I. Development Plan for the Scientific Field

1. Development Program

(1) Use of Artificial Satellites

a. Test Planet-Explorer (MS-T5)

In order to confirm the capabilities of the M-3S II rocket No 1, establish interplanet orbits and acquire techniques of attitude control and superlong distance communications in connection with orbit establishment, test planet-explorer (MS-T5) "Sakigake," which was launched in January 1985, will be used.

b. No 10 Science Satellite (PLANET-A)

For carrying out research on plasma between planets located inside the earth's orbit and to observe Halley's comets in the ultraviolet region, No 10 science satellite (PLANET-A) "Suisei," which was launched in August 1985, will be used.

c. No 11 Science Satellite (ASTRO-C)

For observing X-ray sources in the core of active the Milky Way and thoroughly observing X-ray-generating heavenly bodies, No 11 science satellite (ASTRO-C) "Ginga," which was launched in February 1987, will be used.

d. No 12 Science Satellite (EXOS-D)

In order to make precise observations of the acceleration mechanism of aurora particles and the aurora luminescence phenomenon in the geomagnetic sphere, No 12 science satellite (EXOS-D) "Akebono," which was launched in February 1989, will be used.

(2) Development of Artificial Satellites

a. No 13 Science Satellite (MUSES-A)

No 13 science satellite (MUSES-A) will be launched in FY89 by an M-3S II rocket for the purpose of carrying out research concerning precision marking of the orbit required for planet exploration, control technology and high-efficiency data transmission technology, as well as testing the swing-by-moon technology.

b. No 14 Science Satellite (SOLAR-A)

No 14 science satellite (SOLAR-A) will be used for the high-precision image observation of solar flares during the next maximum solar activity period under Japan-U.S. cooperation. Its development will continue with the aim of an FY91 launch into an approximately circular orbit at an altitude of approximately 550 to 600 km.

c. No 15 Science Satellite (ASTRO-D)

No 15 science satellite (ASTRO-D) will be used for the exploration in the farthest region of space where precision observations will be made from X-ray images and X-ray spectra of various heavenly bodies. Development work will continue with a target launch date of FY92 by an M-3S II into an approximately circular orbit of an altitude of approximately 500 to 600 km.

d. No 16 Science Satellite (MUSES-B)

No 16 science satellite (MUSES-B) is intended for research on a large precision extendable structure mechanism and for testing the phase synchronization that is necessary for a very long baseline interferometer (VLBI) using an artificial satellite. The satellite will be developed for a launch date of FY93 by an M-3S II rocket.

e. Magnetosphere Observation Satellite (GEOTAIL)

The magnetosphere observation satellite (GEOTAIL) will be jointly developed by Japan, in charge of satellite development, and the United States, in charge of launching. The satellite will be used for observation research concerning the structure and dynamics of the extremely long geomagnetic tail on the earth's night side. Development work will continue for a target launch date in FY92.

f. Space Science Experiments (SEPAC) Using Particle Accelerator

The space science experiments (SEPAC) using a particle accelerator will be carried out to clarify the aurora's light emission mechanism, kinetics of charged particles in plasma and excitation of electromagnetic wave motion, by irradiating plasma and electron beams. Preparations will be made for repeat experiments using a space shuttle that is expected to be launched in FY91.

2. Research

For the astronomy-related science observation series, research will be carried out on methods necessary for observing various space radiations for the study of heavenly body phenomena involving basic laws of physics and the genesis and evolution of space.

For the earth environs science observation series, observations will be made on the structures of the upper-layer atmosphere, ionosphere and magnetosphere plasma, and research will be carried out on methods necessary for experiments using the observations in order to understand various physical phenomena between the sun and the earth and changes in the earth's environs.

For the moon and planet exploration series, various observation techniques and devices will be investigated for the study of physical phenomena in the interplanetary space and of the genesis and evolution processes of moon, planets and their atmospheres.

II. Development Plan for the Observation Field

1. Development Program

(1) Use of Artificial Satellites

a. Geostatic Meteorological Satellite No 3 (GMS-3)

In order to improve Japan's meteorological programs and develop meteorological satellite techniques, the geostatic meteorological satellite No 3 (GMS-3), which was launched in August 1984, will be used.

b. Experimental Geodetic Satellite (EGS)

In order to confirm the capabilities of an H-I test rocket (two-stage) and carry out land surveys and geodetic experiments, experimental geodetic satellite (EGS) "Ajisai," which was launched in August 1986, will be used after its orbit is defined.

c. Marine Observation Satellite No 1 (MOS-1)

Marine observation satellite No 1 (MOS-1) "Momo No 1," which was launched in February 1987, will be used for observing marine phenomena, including the color and temperature of ocean surfaces, and for establishing techniques common to all artificial satellites for earth observation.

(2) Development of Artificial Satellites

a. Geostatic Meteorological Satellite No 4 (GMS-4)

For improving Japan's meteorological programs and developing technology concerning meteorological satellites, geostatic meteorological satellite No 4 (GMS-4) will be launched in FY89 by an H-I rocket into a static orbit in the vicinity of longitude 140° East.

b. Marine Observation Satellite No 1 b (MOS-1b)

Marine observation satellite No 1 b (MOS-1b) will be launched in FY89 by an H-I rocket (two-stage) into a solar synchronous orbit at an altitude of approximately 900 km. The satellite will be used for the continuous observation of marine phenomena, including color and temperature of ocean surfaces, and for the establishment of techniques common to artificial satellites for earth observation.

c. Earth Resource Satellite No 1 (ERS-1)

Earth resource satellite No 1 (ERS-1) will be developed to be launched in FY91 into a solar synchronous orbit at an altitude of approximately 570 km. The satellite will be used to establish active observation technology and for observation projects including national land surveys, agriculture, forestry and fishery, environmental protection, disaster prevention and coastal surveillance, with a main purpose of searching for resources.

d. Geostatic Meteorological Satellite No 5 (GMS-5)

Geostatic meteorological satellite No 5 (GMS-5) will be developed with a target launch date of FY93 into a static orbit by an H-II rocket. The satellite will be intended for continuing meteorological observations by a satellite and for improving Japan's meteorological work as well as its meteorological satellite technology.

A relay device will be developed for loading on board this satellite to carry out experiments of relaying disaster signals of a ship to a search and rescue organization.

(3) Developmental Research on Artificial Satellites

Earth Observation Platform Technology Satellite (ADEOS) Developmental research on the earth observation platform technology satellite (ADEOS) will continue. The satellite will be developed to maintain and expand earth observation technology, to develop the technology required for developing futuristic satellites, including an earth observation platform, and for relaying earth observation data, as well as to promote international cooperation in the field of earth observation.

2. Research

For the oceanic and land observation satellite series, observation method research will be carried out using various sensors and information processing methods for marine observation; and applications will be examined for various fields, including information analysis methods for resource search and futuristic sensor studies.

For the electromagnetosphere and solid earth observation satellite series, the ionosphere observation satellite technology will be further developed, the observation technology for more sophisticated electromagnetic environments will be studied, and more precise measurement methods will be studied for the fields of geodesy and tectonics.

For the meteorological satellite series, an effort will be made to use as much Japanese technology as possible in satellite meteorological observations, and analytical method research will be carried out.

Research will also be conducted on a satellite system that will compositize meteorological observations with other purposes and functions, such as oceanic weather observation, land survey/position determination and communications with ships and aircraft.

Furthermore, observation systems for stratospheric ozone and atmospheric carbon dioxide will be studied in order to compile data to be used for coping with global environmental problems, and the two-cycle radar technology aboard the satellites will be studied for use in rainfall observation from space.

III. Development Plan for the Communications Field

1. Development Program

(1) Use of Artificial Satellites

a. Communication Satellite No 3 (CS-3a and CS-3b)

The communication satellite No 3 a (CS-3a) "Sakura No 3 a)," launched in February 1988, and the communication satellite No 3 b (CS-3b) "Sakura No 3 b," launched

in September 1988, will be used to continue the communications service provided by communication satellite No 2 (CS-2), to deal with increased and diversified communications demands, and to advance the development of communications satellite technology.

b. Broadcasting Satellite No 2 b (BS-2b)

The broadcasting satellite No 2 b (BS-2b) "Yuri No 2 b," which was launched in February 1986, will be used to advance the development of broadcasting satellite technology and to eliminate audio and visual difficulties in television broadcasting.

(2) Development of Artificial Satellites

Broadcasting Satellite No 3 (BS-3a and BS-3b)

Two broadcasting satellites No 3 (BS-3a and BS-3b) are the satellites that will, when developed, take over the broadcasting service now provided by the broadcasting satellite No 2 (BS-2), deal with increased and diversified broadcasting demands and promote the development of broadcasting satellite technology. Broadcasting satellite No 3 a (BS-3a) and Broadcasting satellite No 3 b (BS-3b) will be launched by an H-I rocket in FY90 and FY91, respectively, into static orbits in the vicinity of longitude 110° East.

2. Research

For the mobile unit communications and navigation satellite series, methods will be studied for communications with and navigation assistance and control of mobile units, such as ships and aircraft, and research will be conducted on intersatellite communication technology and search and rescue technologies using satellites.

For the fixed communications satellite series, research will be directed toward the Japanization and capability improvement of communications satellite technology, considering satellites targeted for practical utilization.

For the broadcasting satellite series, research will be directed toward the Japanization and capability improvement of broadcasting satellite technology, considering satellites targeted for practical utilization.

Research will also be carried out on experimental data relays and tracking satellites for developing data relay and tracking technology as well as both sophisticated broadcasting and highly functional mobile unit communications satellite technologies. In addition, survey research will be conducted on the direction of future communications satellites, considering the continuation of fixed communications service and the demand for mobile unit communications.

IV. Development Plan for the Space Experiment Field

1. Development Program

Development

a. First Material Experiment (FMPT)

The first material experiment (FMPT) will be conducted in FY91 by Japanese scientists and engineers onboard a space shuttle to test materials under unique space conditions. The development of an experimental system and the training of onboard-experimentors-to-be will be continued in anticipation of the target date.

b. First International Microgravity Laboratory (IML-1) Plan

In order to acquire technology to be used in the space environment of a space station, Japan will participate in the United States' first international microgravity laboratory (IML-1) plan to be executed in FY90, ahead of the first material experiment (FMPT). The development of onboard experimental devices will be continued to allow material experimentation in the plan.

2. Research

For both the material and life science experiment series, research will be done on space experimentation technology, basic experiments will be conducted on ground, the expansion and development functions of buildings in space will be tested, and technology to apply artificial intelligence will be studied.

V. Development Plan for the New Space Activity Base Field, Including Space Station

1. Development Program

Development

a. Space Station Plan

The space station plan calls for the construction of a permanent manned space station on a low earth-circling orbit. With the target date of a FY96 launching via space shuttle, the Japan experimental module (JEM) to be mounted on the space station will be developed under close cooperation between industry, universities and government. Material and life science experiments, scientific and earth observations and communication experiments will be conducted in the module. The JEM development will be coordinated according to the "Space Station Cooperation Agreement" after the agreement takes effect over Japan's activities.

In addition, a small rocket (TR-IA) for space experimentation will be developed to gain the necessary information for the development of technology common to all space experiments in the JEM, and the overall space station plan promotion system will be strengthened.

b. Space Experiment/Observation Free-Flyer (SFU)

The space experiment/observation free-flyer (SFU) will be used for securing space experimentation opportunities to carry out various scientific research projects, including science and engineering experiments and astronomical observations and technical development projects for various advanced industries, and for improving the dependability of the exposed sections and

onboard common experimental devices on the space station-mounted experimental module (JEM). The development of a reusable free-flyer will be continued with a FY92 target date for launch with an H-II rocket.

2. Research

Research activities concerning the space station include elemental technology related to the station, manned support technology, a space environment forecasting system, observation devices onboard a polar orbit platform, system and elemental technology for a common orbit platform, light-gathering solar heat electrical generation technology, and space robot technology. Research will also be done on the operation system for the space station-mounted experimental module (JEM) and the station personnel training system. In addition, the use of a space station in the field of technology concerning static platform communications will be studied.

VI. Development Plan for the Common Technology Field in Artificial Satellite Systems

1. Development Program

(1) Use of Artificial Satellites

Engineering Test Satellite V-Type (ETS-V)

Engineering test satellite V-type (ETS-V) "Kiku No 5," which was launched in August 1987, will be used to achieve the following objectives: the confirmation of the capabilities of an H-I test rocket (three-stage), the establishment of basic technology on a static triaxial satellite bus, the acquisition of independent technology necessary for the development of next-term practical satellites, and the execution of mobile unit communication experiments to improve marine control over the Pacific by aircraft and communications, navigation assistance and search/rescue of the ship.

(2) Development of Artificial Satellites

Engineering Test Satellite VI-Type (ETS-VI)

The development of the engineering test satellite VI-type (ETS-VI) will be continued with a target date of FY92 for launch into a static orbit. The satellite will be used to confirm an H-II test rocket, to establish the large static triaxial satellite bus technology necessary for the development of practical satellites during the 90's, and to develop and conduct experiments on sophisticated satellite communication technology concerning fixed and mobile communications by satellite and intersatellite communications.

2. Research

For basic satellite technology, studies will be made to improve the dependability of electronic parts and to improve the capability of solar batteries to be able to cope with satellites' longer life, larger power requirements and further sophistication of functions. Studies will also be made on the space power source system, high precision attitude control system, xenon ion engine, active thermal control system, antenna system, space bearing and futuristic artificial satellites.

In addition, the standardization of satellite systems, the standardization of part materials and the Japanization of materials and parts will be pursued.

VII. Development Plan for the Common Technology Field in Transportation Systems

1. Development Program

Development of Rockets

a. M Rocket

The M rocket has been developed to use solid fuel in every stage and specifically for launching science satellites. Its development will be continued at the Space Science Laboratory until it becomes fully dependable.

In other words, the M-3S II rocket has come about after the improvement of the second and third stage motors and the change in the first stage vernier rocket of the M-3S rocket. Further development of the M-3S II rocket will be continued with the target launch dates of No 13 science satellite (MUSES-A) in FY89, No 14 science satellite (SOLAR-A) in FY91, No 15 science satellite (ASTRO-D) in FY92, and No 16 science satellite (MUSES-B) in FY93.

b. H-I Rocket

The H-I rocket has been developed as a three-stage model capable of launching a geostatic satellite weighing approximately 550 kg. The H-I model uses the first-stage liquid engine of the N-II rocket in its first stage, a second-stage engine propelled by liquid oxygen and liquid hydrogen, a large solid motor for the third stage, and an inertial guidance system.

The development of the following rockets from this basic rocket will be continued with respective launch date targets:

H-I rocket (three-stage) No 4 to launch geostatic meteorological satellite No 4 (GMS-4) in FY89,

H-I rocket (three-stage) No 3 to launch broadcasting satellite No 3 a (BS-3a) in FY90,

H-I rocket (three-stage) No 6 to launch broadcasting satellite No 3 b (BS-3b) in FY91, and

H-I rocket (two-stage) No 5 to launch earth resource satellite No 1 (ERS-1) in FY91.

For the FY89 launch of marine observation satellite No 1 b (MOS-1b), the reserve H-I test rocket (two-stage) will be used after the completion of necessary repairs.

c. H-II Rocket

The development work will continue for the H-II rocket to cope with the demand for large artificial satellite launches in the 90's. The rocket will be a two-stage model capable of launching a static satellite weighing approximately 2 tons, will use a liquid oxygen/liquid hydrogen engine for the first and second stages because of the successful results of this engine with the H-I rocket, and will use two solid vernier rockets.

In conjunction with the H-II rocket development, H-II test rocket No 1 with an efficiency-verification payload onboard will be launched in FY91 to verify the in-flight efficiencies of the first and second-stage liquid oxygen/liquid hydrogen engines, the solid vernier rocket and the inertial guidance control system.

In addition, the development of H-II test rocket No 2 will be continued with the aim of launching engineering test satellite VI-type (ETS-VI) in FY92.

Furthermore, in order to deal with the demand for launching a space experiment/observation free-flyer (SFU), H-II test rocket No 3 will be developed to realize the launching in FY92. Also, a large faring that will be required for future launchings of large artificial satellites and a multiple satellite simultaneous launching system will be developed.

2. Research

In the rocket application technology area, studies will be conducted on orbit change technology, rendezvous-docking technology, recovery technology, the inter-orbit transport plane and the space shuttle plane.

Other research projects will include those concerning the liquid oxygen/liquid hydrogen engine, the sophistication of the rocket's guidance control, the high-altitude efficiency of rocket engines, and the structure and part materials of rockets.

VIII. Facility Improvement

1. Facilities Necessary for Artificial Satellite and Rocket Development

(1) A thermal vacuum test facility, necessary for large artificial satellite development, a large acoustic test facility, and other testing facilities to test observation devices, to be carried by satellites, and satellite's functions will be improved.

(2) A test facility required for H-II rocket development and a test facility for improving the dependability of the M rocket will be improved.

(3) When the National Space Development Agency of Japan (NASDA) improves testing facilities necessary for development projects, an attempt shall be made to build large facilities that can handle all large devices and machines in a cluster for efficient management and data processing. Consideration will be given to encourage shared facilities between related research and development organizations.

(4) A remote sensing information reception and processing facility will be improved in Japan to provide data for R&D concerning the earth observation system using artificial satellites.

2. Launching Facilities for Artificial Satellites and Rockets

Facilities for range control and radar telemetry and an H-II rocket launch point facility will be constructed on the Tanegashima Space Center. A down range office facility, specifically for the launching of the marine observation satellite No 1 b (MOS-1b), will be established in the Okinawa Tracking Control Station.

The existing facilities at the Kagoshima Space Observation Station of the Space Science Laboratory will be improved to include the launching facility for science satellites and M rockets.

3. Facilities Required for Tracking Artificial Satellites

Tracking facilities will be improved for tracking geostatic meteorological satellite No 4 (GMS-4) and science satellites. A space operation data system (SODS) will also be expanded to cope with simultaneous launching of multiple satellites by an H-II rocket. Furthermore, a central tracking network facility will be established in the Tsukuba Space Center to handle those tasks of satellite operation control and data acquisition that are judged more appropriate to be executed by a single station. A tracking control method using laser will be studied.

In addition, facilities necessary for data acquisition by and control of science satellites will be established.

4. Other Facilities

A ramjet engine testing facility will be established for R&D on the propulsion system technology for space shuttles.

IX. Other Policies

1. Fortification of R&D Capability

National testing and research organizations will be strengthened and expanded to promote their research activities. The R&D Department of NASDA will be strengthened to improve cooperation between research activities at the national testing and research organizations and NASDA's development activities.

2. Promotion of International Cooperation

According to the development plans for the fields of science, observation, space experiments and for the space station, international cooperation with advanced nations as well as developing countries will be promoted. International cooperation will be intensified and promoted in the space development fields through activities at the space department of the Japan-U.S. Standing Staff Liaison Conference (SSLC), the Science and Technology Joint Committees with France, West Germany, Canada and Australia, the Japan-European Space Agency Administrators Conference, and the United Nations Space Peaceful Utilization Committee; preparations for participation in the International Space Year (ISY) activities; invitations of overseas space development personnel; and database updating for information exchange with other countries, including the United States.

3. Steps Concerning Space-Related Agreements

Necessary steps will be taken to ensure smooth execution of space-related agreements, including "The agreement concerning international responsibilities for casualties caused by a space object."

4. Intensification of Promotional and Educational Activities

Achievements by Japan's space development activities will be publicized and their application will be encouraged. In order to obtain citizens' understanding of and cooperation toward space development, comprehensive promotional and educational activities will be strengthened over all areas of space development.

5. Training of Space Engineers

In order to improve both quantity and quality of space-related engineers, staff members of organizations concerned will be sent for training to foreign universities, research institutes and administrative organizations.

6. Space Development Promotional Base Updating

Assistance will be provided to the Tanegashima area fisheries countermeasure project in order to smoothly execute the launchings of Japan's artificial satellites.

X. Budget

The table below indicates the FY89 space-related budget required for the development of artificial satellites and rockets, the updating of facilities and the promotion of special research projects.

Space-Related FY89 Proposed Government Budget Summary Table
(#: Maximum government bond obligation amount) (Unit: ¥ million)

Agency	FY88 final budget			FY89 proposed budget		
	Space development related	Space related*	Total	Space development related	Space related*	Total
Space and Technology Agency	# 102.604	-	# 102.604	# 84.412	-	# 84.412
Space and Technology Agency	98.470	-	98.470	109.062	-	109.062
National Police Agency	-	382	382	-	118	118
Environment Agency	-	-	-	51	-	51
Ministry of Education	# 9.105	# 1.386	# 10.491	# 11.323		#11.323
	13.364	6.427	19.790	12.847	7.938	20.785
MITI	# 9.001	-	# 9.001	-	-	-
	14.089	-	14.089	14.563	-	14.563
Ministry of Transport	# 1.583	# 126	# 1.709	# 1.213		#1.213
	3.089	2.642	5.731	3.601	2.673	6.274
Ministry of Posts and Telecommunications	# 919		# 919	# 44		# 44
	532	2.667	3.199	564	3.455	4.019
Ministry of Construction	-	2	2	-	2	2
Ministry of Home Affairs	-	119	119	-	120	120
Total	# 123.212	# 1.512	# 124.724	# 96,993		# 96,993
	129,543	12,238	141,781	140.688	14.306	154.994

*Budget amounts under the "Space related" heading (outside the estimates made by the Space Development Committee) are given for reference.

Note 1. Because each budget amount in the table has been rounded to million yen, a total amount may not agree with the sum of individual items.

Note 2. The FY88 budgets are the initial FY88 budgets.

FY89 Space Development-Related Proposed Government Budget (#: Maximum government bond obligation amount) (Unit: ¥ million)

Agency	Organization-in-charge	Item	FY88 budget	FY89 proposed government budget
Science and Technology Agency	Research and Development Bureau	Expenses required by the Space Development Committee	56	62
		Expenses required for general administration	35	31
		Expenses required for improving the quantity and quality of scientists and engineers	41	41
		Expenses required for the Tanegashima area fisheries countermeasure project	400	412
		Subtotal	532	547
	Science and Technology Promotion Bureau	Expenses required for general administration	4	4
	National Aerospace Laboratory (NAL)	Expenses required by NAL	# 147	# 792
			1.399	1.754
	National Space Development Agency of Japan (NASDA)	Expenses required for NASDA's investment and subsidy	# 102.457	# 83.620
			96.534	106.757
			Government investment	Government investment
			# 102.457	# 83.620
			87.563	97.287
			Government subsidy	Government subsidy
			8.971	9.470
	Japan Atomic Energy Research Institute	Research expenses for radiation applications	-	-
			Radiation high-tech research	Radiation high-tech research
			# 5.803	# 3.715
			A part of ¥ 2.313 million	A part of ¥ 4.888 million
	Total		# 102.604	# 84.412
			98.470	109.062
Environment Agency	Planning and Coordination Bureau & Air Quality Bureau	Survey and research expenses for pollution prevention	0	51
	Total		0	51
Ministry of Education	Space Science Research Institute	Expenses required for special projects	# 9.105	# 11.323
			13.364	12.847
	Total		13.364	12.847
MITI	Machinery and Information Industries Bureau	Development of unmanned space experiment system	# 9.001	
			3.856	4.487
		R&D on remote resource exploration technology	8.627	8.890

FY89 Space Development-Related Proposed Government Budget (#: Maximum government bond obligation amount) (Unit: ¥ million) (Continued)

Agency	Organization-in-charge	Item	FY88 budget	FY89 proposed government budget
		Subtotal	# 9.001	
			12.483	13.377
	Agency of Natural Resources and Energy	Monitor survey on wide area environmental effects	0	305
	Agency of Industrial Science and Technology	R&D on remote resource exploration technology	1.557	806
		Expenses required for special research projects by testing stations and research laboratories	49	75
		Subtotal	1.606	881
	Total		# 9.001	
			14.089	14.563
Ministry of Transport	Transport Policy Bureau	Expenses required for development of transport technology		# 19
			55	39
	Electronic Navigation Research Institute (ENRI)	Expenses required by ENRI	128	90
	Meteorological Agency	Expenses required for geostatic meteorological satellite programs	# 1.583	# 1.194
			2.906	3.472
	Total		# 1.583	# 1.213
			3.089	3.601
Ministry of Posts and Telecommunications	Communication Policy Bureau	Expenses required for electric communication management	41	7
	Communication General Research Institute	Expenses required for R&D on space communication technology	# 919	# 44
			491	557
	Total		# 919	# 44
			532	564
Grand total			# 123.212	# 96.993
			129.543	140.688

FY89 Space-Related Proposed Government Budget
(#: Maximum government bond obligation amount) (Unit: ¥ million)

Agency	Organization-in-charge	Item	FY88 budget	FY89 proposed government budget
National Police Agency	Communication Bureau	Expenses required for police communications	382	118
	Total		382	118
Ministry of Education	Space Science Research Institute	Expenses required for special projects	# 1.386	
			6.427	7.938
	Total		# 1.386	
			6.427	7.938
Ministry of Transport	Marine Safety Agency	Expenses required for administration of hydrographic programs	125	137
	Meteorological Agency	Expenses required for geostatic meteorological satellite programs	# 126	
			2.260	2.260
		Expenses required for general observation and forecasting programs	83	66
		Expenses required for high-altitude meteorological observation programs	174	210
		Subtotal	# 126	
			2.517	2.536
	Total		# 126	
			2.642	2.673
Ministry of Posts and Telecommunications	Minister's Secretariat	Expenses required for operating satellite communications	373	1.157
	Communication Policy Bureau	Expenses required for electric communication management	3	3
		Expenses required for investing in communications and broadcasting satellite organizations	2.000	2.000
		Subtotal	2.003	2.003
	Communication General Research Institute	Expenses required for R&D on space communication technology	291	295
	Total		2.667	3.455
Ministry of Construction	National Land Geography Agency	Expenses required for geodetic data survey	2	2
	Total		2	2
Ministry of Home Affairs	Fire Defense Agency	Expenses required for maintenance control of radio communication facilities	119	120
	Total		119	120
Grand total			# 1.512	
			12.238	14.306

ERS-1 Sensors Evaluated

43062514 Tokyo DENSHI in Japanese Apr 89 pp 34-35

[Unattributed article]

[Excerpts] [Passage omitted]

Evaluation of R&D of Observation System for Resources Exploration

The Evaluation Subcommittee (chairman: Sho Yamamura, emeritus professor, of Tokyo University), Large-scale Technology Development Committee, Industrial Technology Council has conducted the final evaluation of "The Observation System for Resources Exploration," a large-scale project that MITI has been advancing in its 5-year plan from fiscal 1984, on the occasion of the completion of its R&D. According to the evaluation, the project has obtained many excellent results in the R&D on geological remote-sensing and basic future sensor technology, has contributed to the establishment of the design/manufacturing technology of high-performance sensors, and its influence on making remote sensing practical in the space industry in the future is expected. The main gist of the evaluation report is as follows.

1. Target of R&D: The target of the R&D was to establish a high-performance sensor design/manufacturing technology providing reliable and durable system technology in space in the Earth Resources Satellite 1 (ERS-1), and the target of its R&D basic plan was to establish the mounting specification (the development specification of the proto-flight model (PFM), etc.) of the ERS-1 resources exploration observation equipment.

Therefore, the manufacturing and the function-confirmation experiment of the engineering model (EM) of the mounting observation system of the ERS-1, and their results were analyzed and evaluated, and the mounting specification was established based on the results. During this period, "the ERS-1 observation system specification" on the basic performance that concretized the R&D basic plan, and the concrete and detailed specification was established in the beginning of the R&D period. After that, these specifications were improved with the progress of the R&D of the manufacture of the EM, function experiments, etc., and they were finally established as the PFM mounting specification.

2. Evaluation of R&D: At the test and research institutes under the Agency of Industrial Science and Technology, the R&D on the basic future sensor technology was conducted in addition to trying to complete geological remote-sensing technology aiming at the support of the development of the satellite mounting observation system. They have obtained many excellent results evaluated as a contribution to the establishment of the design/manufacturing technology of high-performance sensors.

Synthetic Open Radar: The values of certain items, such as electromagnetic compatibility of the synthetic open radar, were lower than that of the specification values, but since they could be adjusted by the satellite body, the development and the interface specifications were established after revising the specification values. It can be judged that this has accomplished the object of the basic plan.

Optical Sensor: Optical sensors are classified into the visible near infrared radiometer and the short wavelength infrared radiometer. As to the visible infrared radiometer, all of the specification values established first were attained, and the development and interface specifications were established the same as the original. As the result of tests, certain items of the detector section of the short wavelength infrared radiometer in the optical sensor could not attain the specification values. Therefore, the designs of the detector, cooler, and signal-processing sections were changed appropriately after examination, and the specification values were revised to lower ones. It is considered that the following items should be examined to raise the effectiveness of the short wavelength infrared radiometer image for the oil/mineral resources exploration that can be obtained in actual operation in the future; 1) Use of the visible near infrared radiometer image and the synthetic open radar image at the same time; 2) increasing the calibration frequency on the satellite and upgrading the calibration method using the data of the points where ground truths are confirmed; and 3) upgrading of the image-processing method (after the secondary processing) on the ground.

Data Transmission System: The data transmission system of the mission transmitter and the mission recording device attained all the specification values established in the beginning, and the development and the interface specifications were established. It can be said that the object of the basic plan has been accomplished with these.

Entire Observation System: As the results of these, the ERS-1 observation system specification on the basic specifications for respective observation equipment could have been made almost satisfactorily. As to the development and interface specifications for respective observation equipment, the specification values were revised for the items whose specification values were lower than those of the original ones. The developed observation system made it possible to mount the synthetic aperture radar and the optical sensor on the ERS-1 (1.4 tons), which is considerably lighter than the Seasat (2.3 tons) and the Landsat (2 tons) of the United States, the Spot (1.8 tons) of France, and the ERS-1 (2.2 tons) of the European Space Agency scheduled to be launched. Its synthetic aperture radar and the optical sensor have a performance of 18 meters which is a better resolution than that of those satellites; and its higher optical senser has higher performance capabilities than that of the Earth observation satellites of other countries launched heretofore, such as the stereoscopic vision in the same track as the optical sensor and the spectrum observation in the short wavelength infrared region. It is evaluated that this time R&D has established the design/

manufacturing technology of the ERS-1 mounting observation system, except that the image of the short wavelength infrared radiometer is lower than the original target. It is expected that the calibration method of satellite data and the image-processing method are to be further improved. [Passage omitted]

New Developments in Biotechnology Policy

43063063 Tokyo TSUSAN JANARU in Japanese Mar 89 pp 37-39

[Article by M. Masuda, chief, Bioindustry Office, Basic Industries Bureau, Ministry of International Trade and Industry]

[Excerpt] Although applied engineering technology has been used on organisms for a long time, the scope of its application to industry is rapidly spreading since the development of recombinant DNA technology in 1973. Consequently, a new industrial field, bioindustry, which has its foundations in biology and applied biological technology (biotechnology), has recently emerged, in diverse fields such as pharmaceuticals, food, cosmetics, reagents, amino acids, etc.

Therefore, in this article, I wish to clarify the significance of bioindustry as I look back on its history since MITI became involved with bioindustry policies in 1981, and introduce future developments in biotechnology policies.

Developmental stage

(Post-Heisei First, 1989)

Based on the popularization of first generation biotechnology, such as recombinant DNA technology, as an industrial technology, the new era beginning with the first year of Heisei (1989) is a time to strive for bioindustry to integrate into society as an industry having new values for the 21st century, namely, values such as being "gentle to humans and to the environment" while (1) promoting biotechnology to integrate into and contribute to people's lives through broad product development and (2) having viewpoints of emphasizing basic research aimed at pioneering in greatest unknown frontiers left to mankind and contributing to an international society and the global environment.

Today, environmental problems of global scale, problems of wastes reaching beyond national borders, etc. are posing a need for reevaluation of the relationships between human activities and the environment from a new perspective. Consequently, I believe we are entering an era where in considering the industrial values, e.g., items such as renewability of natural resources, mildness of manufacturing processes, compatibility of products to the human body and environment, biodegradability of wastes, should be evaluated on the same level as previous value references of efficiency and usefulness.

Bioindustry is an industry that is compatible with the demands of such an era and has values different from conventional industries in that its products are truly compatible with the human body and ecology and are endorsed by knowledge obtained from biological organisms using renewable resources of biological origin as raw materials and processes which occur under mild conditions governed by the organisms themselves. The products are highly biodegradable and scarcely cause waste problems because of their biological origin.

Consequently, it is desirable to develop bioindustry in the future as "a technology, products and industrial system having new values of being gentle to humans and the environment" and plan its healthy development.

In the enforcement of policies, as well, we are to strive for policy development based on new era awareness and ideology centered around four tenets: (1) the promotion of second generation research and development, (2) the improvement of an industrial base which incorporates a regional expansion perspective, (3) the perfecting of safety, and (4) the consideration of international contributions in various policy developments (Table 2).

Table 2: Policy structure of the Biochemical Industry Division (provisional name)

Policy ideology: Develop industries that are gentle to humans and the environment

Three policy goals (I, II, III); four policy tenets (l, 2, 3, 4):

I. Pioneering new frontiers

1. Promoting research and development

Promote more advanced basic research and development

(1) Aim for the use of more diversified biological resources

... Marine biotech project

(2) Aim for the application of more complex vital functions

... Applied functional protein aggregate technology

(3) Aim for the application of more extensive materials of biological origin

...Biodegradable plastics project

(4) Aim for the elucidation of more advanced vital functions

... Promotion of the Human Frontier Science Program

II. Aim to incorporate bioindustry into society

2. Improvement of the industrial base

In order to promote smooth application of research results to industrial activities and penetration of biotechnology into people's lives through products of daily use, support industrialization of the technology by tax and loan systems.

(1) Establish bioindustry taxation system (7 percent tax exemption or 30 percent special repayment)

(2) Actively use the loan system to promote biotechnology industrialization (Japan Development Bank, Small Business Finance Corporation)
(3) Promote standardization

3. Perfect safety measures

Strive to perfect safety with international harmony by responding to people's expectations and cooperation with other countries.

(1) Enact safety standards for bioprocess equipment

...Perfect safety measures for use of organisms in factories

(2) Enact safety in an open system

...Promote the use of organisms in an open system such as wastewater treatment

(3) Prepare a list of safe organisms usable in industry

III. Toward contributing to the international economic society

4. Promotion of international contributions

In order to respond to the expectations of other nations regarding Japan's long history in the application of organisms, transmit Japanese knowledge in research and development, safety, and industrial cooperation.

(1) Contributions in research and development...1. (1)-(4)

(2) Contributions to developing nations...active use of ODA [Official Development Assistance] (Indonesia, etc.)

(3) Contributions to OECD [Organization for Economic Cooperation and Development]...Harmonization of measures taken for safety

(4) International exchange...Hold international biotech fairs, etc.

For the overall development of bioindustry policies from the new perspective as explained above, MITI decided to dissolve and upgrade the Bioindustry Office in the Basic Industries Bureau to the Biochemical Industries Division (provisional name) from FY89.

With the establishment of industries with new values, we wish to develop bioindustry policies while anticipating an industrial philosophy that is fitting to the new era to become established in society as it fuses with the life and culture.

Human Genome Project

90CF0021A Tokyo SEIMEI KAGAKU TO SEIMEI KOGAKU TOKUBETSU IINKAI in Japanese 25 May 89 pp 1-12

[Text] Report by Bioscience and Bioengineering Special Committee, On the Promotion of the Human Genome Project, 25 May 1989; The Science Council of Japan, Bioscience and Bioengineering Special Committee

This report summarizes the discussions that took place at the 14th session of the Bioscience and Bioengineering Special Committee of the Science Council of Japan.

Committee Chairman	Eiji Inoue	(The Seventh Department)
Secretary	Tatsuo Ishikawa	(The Fourth Department)
Secretary	Tetsuo Nakajima	(The Sixth Department)
Member	Kazuo Aoi	(The First Department)
Member	Shin Yamamoto	(The First Department)
Member	Toshio Sawanobori	(The Second Department)
Member	Minoru Tanaka	(The Second Department)
Member	Kenichi Inada	(The Third Department)
Member	Ikuo Takeuchi	(The Fourth Department)
Member	Sachio Hiramoto	(The Fourth Department)
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Member	Akiyoshi Mitsuishi	(The Fifth Department)
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Synopsis

The human genome project, that aims at determining the entire DNA sequence of human genome, is expected to significantly impact on academic research; therefore, should be urgently promoted as a national priority. In order to do so, however, a promotional organization should be established with comprehensive responsibilities to draw up a basic plan, form an execution plan, coordinate inter-agency conferences, promote international cooperation and update databases and repositories. Along with this promotional organization, a separate, but closely cooperating, overseeing organization should be established to execute balanced policies for the purpose of judging objectively and impartially social, legal and ethical problems associated with the execution of research plans.

I. Preface

The human genome project is an ambitious research plan that aims at advancing drastically the understanding of human genetic information and the clarification of human genetic functions. The project's more specific objectives include the determination of the total DNA base sequence of gene-containing human genomes, the determination of the positions of human genes and DNA segments in a chromosome, the studies of comparative research and related technology development in

laboratory animals and plants. Since 1986, discussions have taken place in the U.S., Japan and European countries on this research project. In 1988, actual research projects have started mainly in the U.S.

This project is expected to impact significantly on scientific research in the widely ranging fields of basic biology, biochemistry, physiology, medicine, pharmacy, robotic engineering and information processing. The project includes the clarification of human genetic programs, the drastically improved countermeasures against hereditary diseases, the discovery of unknown physiologically active substances, and the development of a base sequence analyzing robot and massive information processing technology. If the technical development in the bioscience and bioengineering-related fields can progress through the work of this project, there should be no doubt that the project will contribute to human welfare by spurring progress in many other scientific fields.

Although most of these project activities can, in principle, be accomplished with current technology, the present problem is how to conquer the bottleneck of the enormous cost and the long time involved for completion.

This project is expected to cause various repercussions on the human society. These include all kinds of ethical problems in connection with the application of research accomplishments; and direct project-originating social and legal problems, including problems of informed consent (consent after receiving explanations), privacy and confidentiality for persons who offer biological specimens for research, problems of information management, problems of opening research plans and results to the public, and problems of intellectual property on research materials and accomplishments.

Since 21 October 1988, in the 14th session of the Bioscience and Bioengineering Special Committee of the Science Council of Japan, the committee, bearing in mind the minutes of the 13th Session of the Committee, discussed with an emphasis on how Japan should handle the human genome project. Conclusions of the discussions are given below.

II. Promotion of Human Genome Project

Because of its potentially significant, positive impact, the human genome project is a sufficiently important research project for Japan to promote with urgency and as a priority. On the other hand, because this project is expected to influence the human society in various ways, these two sides must be comprehensively taken into consideration, and balanced policies must be advanced with utmost precaution in promoting this project.

III. Establishment of Human Genome Project Promotional Organization and Its Objectives

Many government ministries, agencies and research organizations will be involved in promoting the human genome project. The expertise disciplines of researchers who will directly lead respective projects cover a wide range. Therefore, it is mandatory that labor and expense will be spent effectively in selecting research topics through close contacts between government agencies and their affiliate organizations as well as between researchers in respective specialized fields and their groups. In order to do so, an organization, that promotes the overall human genome project, needs to be inaugurated soon. For the establishment of the organization, however, the independence of each researcher and each group of researchers should naturally be highly respected.

The main objectives of this promotional organization are as follows.

1. To draft an overall basic plan for the project
2. To draw up an execution plan based on the basic plan
3. To coordinate liaison and discussions between agencies and between researchers at different research organizations for research project execution
4. To be a window for international cooperation concerning this project
5. To deal with problems concerning the establishment and updating of a storage/supply facility (the so-called repository) for databases, DNAs and cells.

Parties with which this organization deals with in international cooperation are expected to be foreign governments, EC and private organizations including HUGO (Human Genome Organization). This promotional organization is also responsible for examining whether the repository should be a part of the international system and, if so, who should share the responsibility of managing it.

This promotional organization must be made to be able to handle research progress with flexibility and mobility. Also, in order to deal with concrete problems related to research execution, this organization needs to have committees composed of government agency personnel in charge of bioscience and bioengineering and experts in the related fields.

IV. Establishment of Overseeing Organization to Deal With Social, Legal and Ethical Problems and Its Objectives

In order to deal with social, legal and ethical problems, which are created by the project's activities, an overseeing organization needs to be established separately to work closely with the above-mentioned promotional organization. The main objectives of this organization are listed below.

1. To establish standards for the protection of specimen providers on securing informed consent, privacy and confidentiality

2. To draw up standards for information management and public information on research plans and results

3. To draw up policies regarding intellectual property problems

4. To form guidelines on ethical problems in connection with applications of research results.

It is desirable to begin examinations on the protection of specimen providers and the management and publication of information at the same time as the project is inaugurated to be able to show the standards as soon as possible. Each research organization should establish its own ethical committee that will deal with actual problems on the basis of the to-be-established standards. As far as the intellectual property issue is concerned, Japan's policies must be urgently decided in order to avoid unfair monopolies by an advanced nation, a researcher or a group of researchers on research materials, enormous information concerning human life functions obtainable through analysis of research materials, or other research results, because, as the project progresses, some accomplishments will undoubtedly be made.

Members of this overseeing organization must judge the right or wrong of research plans objectively and fairly, so as not to allow artificial manipulations of human life concerning the base of humanity at all. At least a part of the members should be researchers who are not in the disciplines of natural sciences related to this project, and it is desirable that any members of this overseeing organization do not serve on the promotional organization. One way to ensure this membership make-up is to have the Science Council of Japan recommend candidates for the overseeing organization memberships.

V. Postscript

This report has been compiled to seek opinions from various sources on the above-discussed conclusions.

This Special Committee plans to continue working in order to draw recommendations on the promotion of the human genome project and the establishment of the promotional and overseeing organizations.

Attached Materials, On Promotion of the Human Genome Project; Report by The Bioscience and Bioengineering Special Committee, The Science Council of Japan

Contents

1. What is the Human Genome Project

1.1

Human genome is a set of DNAs contained in each human cell. DNA is really a gene itself, and hereditary information is determined by the arrangement of four types of base (A, T, G and C) contained in DNA. Bases form pairs, such as A=T and G≡C, in a DNA molecule, and the number of base pairs in a human genome is estimated to be three billions.

1.2

The human genome project is a research plan that ultimately aims at determining the complete sequence of human DNA bases, deciphering human hereditary information, and advancing drastically and understanding of human genetic functions. It was proposed in 1986, and in 1988, after thorough examination by many top level researchers, several countries led by U.S.A. began to put the plan in action.

1.3

Humans are estimated to have approximately 100,000 genes. With the exception of a few, these genes are arranged in a row over 24 types of chromosomes (22 types of normal chromosomes and a pair of sexual chromosomes) in a cell nucleus.

1.4

In higher organisms, such as humans, a gene is normally divided into several segments called exon that commands protein syntheses. A portion of DNA, called intron, with unclear functions is sandwiched between two exons. Also, there are many DNAs (spacers), with undefined functions between genes. The exon portion is considered not more than five percent of the total genome. Because the genome is made up of these DNAs, this project intends to completely determine even these in-between base sequences.

1.5

The project is roughly divided into four parts:

A. Determination of the total base sequence of human DNA

B. Chromosome mapping, i.e., the determination of the position in a chromosome for known human genes and severed DNA segments (called genetic mapping and physical mapping, respectively)

C. Determination of base sequences of creatures other than human

D. Development of technology required for the above .

1.6

Of the above-listed parts, Part A is the direct objective of this project. However, the ultimate objective of this project will not be achieved by only determining the base sequence. Therefore, research on Part B will be necessary. Thus far, the existence of 4,300 genes, including some not clearly identified, is known in humans. Chromosome mapping has been completed for approximately 1,400 of these genes. As the number of human genes is estimated to be approximately 100,000, only 1/20th of them have been found to exist and, in turn, mapping has been completed for less than one third of the existence-proven genes. Furthermore, approximately 2,000 DNA segments with unclear functions have been mapped out. In order to better understand human genetic information and clarify the functions of many genes, it is necessary to emphasize the promotion of the completion of this chromosome mapping. Part C, above, is a plan to advance the analysis of the base sequence of laboratory animals and plants (mice and yeast fungi, for example), which have been highly analyzed genetically, and by comparing the results with that of humans, to gain deeper insight to more of human genetic information and genetic functions. Part D, above, includes the creation of database, the development of new computer hardware and software, and the development of DNA manipulation technology.

2. Past Progress (as of Apr 89)

2.1

This project was first announced in 1986. In that year, the U.S. Department of Energy (DOE) announced the plan to determine the DNA base sequence for the entire human genome. DOE has recently been reported to have begun preliminary research at three research institutes under its jurisdiction (Nature, 331, 103, 88), and is said to be asking $18 million for the FY89 outlay (based on the OTA report mentioned under 2.2).

2.2

Subsequently in 1988, the Office of Technical Assessment (OTA) of the U.S. Congress published a detailed report concerning the human genome project (Mapping Our Genes. The Genome Projects: How Big, How Fast. Government Printing Office, 88). About the same time, the U.S. National Research Council (NRC) also made public a similar detailed report. According to this report, human genome research is particularly important, all-out research should be started immediately, and organizational actions and special budget measures (roughly estimated to be $200 million per year for 15 years) will be required for the research. Genetic research on creatures other than human is said to be equally important (Mapping and Sequencing the Human Genome, National Academy Press, 88). Our discussion materials owe mostly to these reports by OTA and NRC.

2.3

The U.S. National Institute of Health (NIH) was funding the human genome project-related research presumably with an annual amount of $200 million (Nature, 332, 99, 88). However, in FY88, an additional spending of $17.3 million was approved by the U.S Congress as a special budget for genome research. For the same FY89 budget, former President Reagan requested $28 million (ditto). The Office of Human Genome Activities, head by Dr. James Watson, was established within the NIH, and in December 1988, the research monies were allocated to 55 research institutes all over the U.S. (Nihon Keizai Shimbun, 24 Dec 88). Also, in the beginning of 1989, the Program Advisory Committee on the Human Genome (Chairman: N. Zinder) began concrete examinations on research targets, database, need for establishing a central organization, ethics and education/training (Science, 243, 167, 89).

Separately, the Biotechnology Information Center has been established in the million has been approved by the Congress for the Center to develop software and a database system to process an enormous amount of data obtained by the human genome project (Nature, 338, 104, Mar 89). Further, it appears that the National Science Foundation, the U.S. Department of Agriculture, and Howard Hughes Medical Institute, a non-profit organization, will fund this project (Nature, 337, 108, 89). President Bush has requested an FY89 budget of $130 million (Japan Times 26 Apr 89), though it is not clear which agency is requesting this budget.

2.4

In November 1988, the U.S. Congress approved the establishment of the Biomedical Ethics Board. This board, set up directly under the President until November 1990, will deal with various problems, particularly concerning the human genome project.

2.5

In Europe also, many countries are seen tackling this project. For example, in 1987, the Italian Research Council (CNR) announced the start of a human genome project, led by a Nobel laureate Re. Dulbecco, with a total investment of L 20 billion (approximately $15 million). In October 1988, the Workshop on International Cooperation for the Human Genome Project with the main theme of international cooperation was held in Valencia, Spain, and the Valencia Declaration on the Human genome Project was announced to limit the project's accomplishment only to improve human dignity, and to offer the accomplishments freely to scientists in any country. The number of types of research DNA segment clones, which are to be preserved, is alleged to be 90,000 (ATCC Quarterly Newsletter 8 (4), 88). U.S.S.R. plans to preferentially advance this type of research and take budget measures in the beginning of 1989 (Science 242, 1244, 88), actually planning to invest approximately $64 million according to a later report (Japan Times, 26 Apr 89). Furthermore, the British

government has decided to allocate a special budget ($11 million for three years) to the human genome project, and plans to establish a database and a DNA library at the Clinical Research Center (CRC) of the Medical Research Council (MRC) to use the database and library as the core of technical development and resources (Nature 338, 104, Mar 89). The Imperial Cancer Research Fund (ICRF) appears also to be keenly interested in the DNA library of MRC.

2.6

Several movements are also seen in EC. One of them is the BRIDGE (Biotechnology Research and Innovation for Development and Growth in Europe) Plan which will start in 1990. The Plan in part will try to determine the base sequence of yeast fungus at a cost of $50 million. Another research project in medicine, including the human genome project, has been planned with a budget of $25 million within the Program of Predictive Medicine and Novel Therapy. This program also includes the improvement of human chromosome mapping resolution, the establishment of a library network of sequenced DNA clones, the improvement and propagation of genetics advanced technology, and the development of comprehensive database and data processing technology (Science, 3, 599, Feb 89). The use of central resources is said to be mandatory to avoid excessive decentralization of the human genome project in Europe (ditto). After discussions at the European Parliament in February 1989, the human genome project was renamed the human genome analysis and the investment of 15 million EUC has been requested.

2.7

Meanwhile in Japan, Mr. Akimitsu Wada of Tokyo University began the development of an automatic base sequencing system with money from the science and technology promotion coordination fund of the Science and Technology agency (STA). Subsequently, the Human Gene Analysis Subcommittee has been established within the Council for Aeronautics, Electronics and Other Advanced Technologies of STA, and in June 1988, the subcommittee submitted a report on the deliberation topic, "the promotional policies for comprehensive R&D concerning human gene analysis." This report is composed of three chapters of the significance of human gene analysis, the current status and the approaches, and it states that the project has far-reaching significance in potentially becoming an epoch-making achievement in science history. Although this report particularly emphasizes examinations of technical aspects, it discusses the unimaginable significance in discovering, through technology, the entire genetic structure of human's own life phenomena, and the need of aggressively promoting international cooperation and sharing fair responsibility in the international community. Incidentally, the expression of "human gene analysis" is used here to mean human genome analysis.

2.8

The Human Frontier Science Program is scheduled to start activities in October 1989. The program is supposed to take up research topics including the genetic information manifestation function and the morphological formation function ("Promotion of the Human Frontier Science Program," distributed by the Bioscience and Bioengineering Special Committee). A keen expectation from overseas is frequently rumored that the human genome project will be promoted as a part of this program. In March 1989, the symposium on "Molecular Approaches to the Human Genome" was held, and overseas speakers participated in it.

2.9

Under the special cancer research subsidized by the science research budget of the Ministry of Education, the "Human Gene Analysis and Cancer Research" group reported in 1987 the results of examinations mainly of technical problems involved in the human genome project and the specific research projects to be established (The compiled research reports of the special cancer research subsidized by the FY87 science research aid fund of the Ministry of Education). In January 1988, the symposium on "Medical Development of Human Gene Analysis," a comprehensive research project supported by the science research budget, was held, and the significance of this program, the expected development in related fields and the technical problems were discussed. In addition, the Special Research Field Promotion Subcommittee of the Science Council, the Ministry of Education, mentions in its February 1989 interim report on the "Promotion of Human Genome Program" that this research program holds potentially significant scientific and social meanings and Japan as a nation needs to promote the program.

2.10

International activities have been flourishing. In April 1988, the Fifth International Summit Conference on Bioethics was held in Rome under the sponsorship of the Italian government, and the human genome project was its central discussion topic. Although it was pointed out that important and complicated ethical and social problems might be caused by research achievements, predictions were also made for the success of this project and its immeasurable contributions to disease prevention and treatment. In this conference the recommendation to conduct "research by each nation and by international cooperation to achieve results quickly in this field and propagate the results" was adopted. Incidentally, the first session of this conference was held in Japan by the former Prime Minister Nakasone's advocacy, the conference was to aim its recommendations to the seven nations of the summit conference (The Hastings Center Report, Aug 88).

2.11

In October 1988, the inaugural general assembly of the Human Genome Organization (HUGO) was held in Switzerland for promoting international cooperation with the human genome project. Professor V. A. McKusick of Johns Hopkins University was selected for the chairmanship of the council and Professor Kenichi Matsubara of Osaka University became one of the Vice Chairmen.

2.12

The Conference of International Organization of Medical Sciences (CIOMS), of which the Science Council of Japan (SCJ) is a member, has decided and has been making preparations, with the cooperation of the CIOMS subcommittee established under the Seventh Department of SCJ, to hold an international conference in July 1990 in Japan mainly to discuss ethical problems involved in the human genome project.

3. Expected Results

3.1

Japan as well as other nations are looking forward with high hope to accomplishments of this project. In other words, everyone thinks that this project will impact very significantly on many scientific fields, in particular the three fields listed below.

A. Basic biology, biochemistry and physiology

B. Medicine and pharmacy

C. Robotic engineering and information processing

In addition, this project is expected to effect the following:

D. Improvement of the scientific research system.

These include those fields, including the diagnosis of hereditary diseases, in which goals are expected to be reached in the comparatively near future (see Section 3.5), and those fields, including the clarification of the genetic program for sophisticated functions of the neural system, that are targeted for completion in the distant future (See Section 3.2).

3.2

In the fields of basic biology, biochemistry and physiology, drastic advances will undoubtedly be made in the clarification of the physical bases for the genetic program of higher animals, particularly human. Because of that, the understanding in the following areas is expected to advance significantly:

1. The principle of the composition of human genome
2. The functions and biological significance of intervening DNA sequences
3. The mechanism of genetic manifestation
4. The generation and differentiation-controlling genes and their functions
5. The similarities and differences in genome compositions between species and their significance
6. The evolution of genomes and the generation of biological systems
7. The genetic programs to control high-degree functions, such as the nervous system, immunity system and metabolic system.

3.3

In the second field of medicine and pharmacy, research in the causes, diagnoses, prevention and treatments of many diseases will certainly be advanced. Also, through the decipherment of hereditary information contained in genomes, great hope is placed on the discovery of substances with unknown physiological activities and the eventual industrial production of new drugs. Particularly significant contribution is anticipated in the field of research concerning hereditary diseases that are at least partially caused by genetic factors.

3.4

There are three types of hereditary diseases:

1. Single gene diseases caused by one or one pair of mutant gene(s) the so-called hereditary disease)
2. Inherited diseases, in the narrow sense, caused by multiple genes and environmental factors (so-called multi-factor diseases)
3. Chromosomic abnormality.

3.5

The majority of the 4,300 human genes, which are now known to exist, are the ones that, when they undergo mutation, can cause hereditary diseases. However, the abnormality on the molecular level has thus far been known on only approximately 400 of these hereditary diseases. As the human genome project advances, the causes on the molecular level should be clarified for most of the other hereditary diseases. In a narrow sense, the hereditary diseases include congenital abnormalities, cancers, high blood pressure, diabetes, circulatory organ diseases, certain mental disorders and chronic diseases with a high frequency in certain populations. The advancement of the human genome project should make it possible to identify a particular gene causing each of these diseases. In addition, a volume of information is expected to be gained concerning the molecular mechanisms that cause chromosomic abnormalities. However, the most direct contribution by the human genome project will be research progress on the causes, diagnoses, treatments and preventions of hereditary diseases including all those mentioned above.

3.6

As the human genome is further deciphered, it will be possible to predict the existence of physiologically active, unknown substances from the base sequence. In the future, these substances are expected to help develop new areas in biochemistry and pharmacy, and eventually to open a road to the industrial production of drugs.

3.7

The reason for the expectation of the development in the third field of robotic engineering and information processing is that, as will be later discussed in 4.2 and 4.3, the progress rate of this project is heavily dependent particularly upon the development of the base sequencing technology, and the technology to process massive obtained data.

3.8

The expectation of the improvement in research system, the fourth area of impact by the project, means that, because of the enormous scale of this project, a system of sharing and cooperating inside and outside Japan is expected to be nurtured.

3.9

Once technological development advances in bioengineering and related fields through this project, progress will undoubtedly be stimulated in many research fields other than those mentioned above, including DNA base sequence determination for higher plants, and future advancements in breeding and agricultural sciences through the applications of the base sequence information.

4. Technical and Economic Problems

4.1

Unless the time required for the completion of this project becomes an issue, the majority of the objectives of the human genome project are considered achievable, in principle, through the combinations of existing technologies. The outlay including the improvement of technologies is, according to the NRC's estimate discussed in the section 2.2, ¥200 million per year and ¥3 billion for 15 years.

4.2

Today in Japan, the physical mapping has almost been 100 percent completed for coliform bacillus genome with approximately five million base pairs. As a next step, the three to four year plan is about to start to determine the complete base sequence. Because the human genome has approximately three billion base pairs, it would require approximately 2,000 years, by simple calculation, to determine their sequence. Thus far, the longest human gene, whose base sequence has actually been determined, is the growth hormone gene with a length of 70,000 base pairs. Other than human genes, Cambridge University of England determined the sequence of the majority of 230,000 base pairs of cytomegalovirus and spent one man-year work on 20,000 base pairs (Science, 242, 1245, 88). ON this basis, 100 workers would need 1,500 years to determine the base sequence of the human genome. Thus, in order to actually execute the human genome project, approximately 100-fold improvement of the technological level is necessary. Research projects to support the execution, particularly the automation including the development of robots to do simple work, should also be carried out along with the sequence determination work itself.

4.3

The worst bottleneck in the determination of human genome base sequence is, in addition to the above-mentioned time requirement problem, the existence of repeating sequences in the genome. Some repeating sequences, called satellite DNAs, show their repetition frequency of up to 10^{5-7}. Elsewhere, some DNAs are known to repeat with a frequency of several hundred to several thousand. Such information tends to contain gaps between individual researchers, and in order to accurately determine the sequence of the particular DNA segment by reconstituting obtained data on the segment, it is believed that a new analytical technique and information processing technology need to be developed.

4.4

Needless to say, the economic problem is the problem of procuring the huge outlay required for the project, and using it effectively. In this connection, researchers of many nations expressed the desire that, in order to execute this project, the research outlays for other areas should not be sacrificed but independent outlays should promote other research projects.

5. Anticipated Social and Ethical Problems

5.1

The human genome project aims to completely clarify, in a sense, human's basic blueprint. Because the project is predicted to impact all aspects of the human society, various social and ethical problems listed below are expected to arise.

5.2

First of all, some suspicions, that were directed toward this project itself, are believed to have arisen from a sense of incongruity toward research targeting human life. Apprehensions have been expressed: can we let science professionals alone be responsible for such a project, will the scope of research targets be expanded without any restrictions, and it is guaranteed to have research plans and activities published?

5.3

One of the social and ethical problems brought forth by this project itself is the problem of informed consent (consent after given explanations). It is extremely difficult to limit the scope of informed consent to be obtained from people who offer test specimens, such as cells and organs, because there are many unknowns in accomplishments to be made in this project.

5.4

There is yet another problem of the assignment or ownership of various biological research samples and research accomplishments. The question is who, e.g., a sample-offering individual, a sample-analyzing researcher, his group, a research organization, university, corporation or country of his affiliation, should have the right over samples and accomplishments. In particular, concern is frequently expressed about the monopoly by certain groups of people over a research accomplishment. One of the objectives of the proposal to promote this project through international cooperation seems to be to prevent such monopolies.

5.5

Socially and ethically serious problems will probably arise at the time of application of research accomplishments. One of these problems is carrier diagnosis. Carrier diagnosis is to detect the presence of diseased genes retained by a person before the patient or any of his offspring suffers from the disease. With the progress of this project, the carrier diagnosis method will undoubtedly be advanced rapidly. If, at that point, a treatment method for that disease has not been established, a serious situation should arise depending on what countermeasures will be taken.

5.6

Similarly, the number of diseases, for which prenatal diagnosis can be applied, is expected to rise rapidly and the issue of artificial abortion is expected to assume an aspect of further complications, if proper countermeasures are not taken.

5.7

Then, there is the problem of privacy or confidentiality. In some countries, there are said to be corporations that will decide hiring depending on the result of the test for the presence of diseased genes (Kagaku Asahi, 49, No. 1, 89). If the application of this project's accomplishment is not appropriate, then a new problem of discrimination might arise. In fact, West Germany's congress is reported to have objected to this project because the project is based on the same principle as Nazi's eugenics (Nature, 336, 416, 88), and Member B. Haerlin (West Germany) of the European Congress is reportedly making a move to legislate to prevent abuses of research accomplishments (Science, p 599, 3 Feb 89). This legislation intends to ban genetic treatments of somatic cells and include the historical study of eugenics within the scope of this project (Nature, 338, 104, Mar 89). Also reported is the inauguration of a working group, headed by E. Winnacker, the director of the Molecular Biology Research Institute of Munich, to examine the social and ethical sides of this project (Science, p 599, 3 Feb 89).

5.8

Once the existence of diseased genes is clarified, there will be experimenters who try to achieve disease prevention by replacing diseased genes. This is the so-called genetic treatment. If genetic treatment is attempted on generative cells, introduced genes will be inherited by descendants; as a result, artificial changes will be made to the genetic composition of organismic human population. Today, this would be extremely dangerous because the true nature of adaptation by an organism called "human" is not yet completely clarified. It will be even more dangerous if a man comes up with a desire to modify "human" based on his peculiar "normal" concept.

6. Discussion Topics

6.1

The Bioscience and Bioengineering Special Committee (BBSC) of the Science Council of Japan at its 14th session had concentrated discussions on how Japan should handle the human genome project which has started on 21 October 1988.

Discussion topics were as follows:

A. Should Japan deliberately promote this project? Or, should individual researchers and/or corporations independently be allowed to carry out their own projects, even though there may be duplications of research topics, labor and outlays?

B. If the government is to be the promoter, what kind of research organization will be desired? Should it be up to ministries and agencies? Will a central organization be necessary to plan the projects's details including budgets, and then coordinate between government agencies as well as between industry, government and universities? How should the concept of establishing the Bioscience Research Education Promotion Conference (tentative name), which was proposed in the BBSC's 13th session report, be handled in relation to this project:

C. How should international cooperation be handled? Should this problem be left up to HUGO (see 2.11), a civilian organization? Should a cooperative system at the government level be established for this? What should be done to prevent the monopoly of data by a few advanced nations?

D. Where should social and ethical problems be discussed? Should a problem be decided, on a

case-by-case basis, by a committee within each research institute or university? Or, should an ethics examination organization, which also sets up guidelines on a national level, be necessary?

E. How should a storage/supply facility (repository) for database and DNA/cells be organized? Should it be a part of the international system? If so, how should responsibilities be shared? What organization should represent Japan to discuss the responsibility assignment?

F. Is there a need to establish a central organization to discuss and handle, in a unified fashion, the above-mentioned matters? Should the Science Council of Japan make recommendations or requests concerning this organization? When should that be done?

6.2

Discussions on the above topics were summarized under the title of "Report by Bioscience and Bioengineering Special Committee - On Promotion of Human Genome Project," and in March 1989, each department, the related special committee and the research liaison committee were requested to review the summary report and respond. Some of the major issues pointed out after the review are listed below after the BBSC subsequently examined further.

A. How should the organization and missions of the central organization be defined? Should a separate central checking organization not be established to deal with social, ethical and legal problems, in parallel with the central organization which is responsible for promoting the project? In order to better define the positions of these two central organizations, could both of them be under a new department within the Science and Technology Council of Japan, for example? Should it not be desirable to have the same personnel belong to the central checking organization as well as to the project-promoting central organization? Should it not be necessary for the central checking organization to include members other than natural scientists, and for both central organizations to be flexible and mobile organizations in order to react promptly to a new development? Should the Science Council of Japan be obligated to play an important role in these central organizations?

B. Should extremely careful consideration be given not to allow the project's results to be applied for the artificial manipulation of human life that might be concerned with the basis of humanity? At the same time, should sufficient consideration be also given to the promotion of research in the fields of organisms other than human, by noting that accomplishments in technology development by this project will contribute to non-human organism research and, in turn, to the welfare and progress of the human society?

C. Should it not be essential to keep in mind the importance of basic research and technology development as research objectives and to emphasize those fields in which Japan can contribute best?

D. Because this project requires an enormous outlay, should it not be necessary to appropriate an independent budget for the execution of this project, so as not to cut outlays for other research areas?

E. How should harmful effects, that may be caused by the central organization, be prevented?

The BBSC has taken steps to publish the summary report "The BBSC Report - On Promotion of Human Genome Project," after revision of the above-mentioned items on the basis of the above discussions.

Fujitsu's Activity in Defense Technology Development

43062517 Tokyo ZAIKAI TENBO in Japanese Jun 89 pp 170-174

[Excerpt] Fujitsu advanced in this field seriously only 8 years ago. How does this "amateur group," which is short of engineers and has difficulty in understanding technical terms, challenge the leaders Mitsubishi Electric (in third place) and Toshiba (in fifth place)....?

The major antisubmarine patrol aircraft of the Japan Maritime Self-Defense Force (MSDF) is the P3C. The number of antisubmarine patrol aircraft possessed ranks second in the world, next to the United States. The antisubmarine patrol capability by the fixed wing is above the total of the United Kingdom and France. A certain MSDF chief of staff explains, "Put the map of the Japanese Islands and the surrounding seas on that of European NATO countries and Japan's defense area is larger. So, it is not strange that Japan possesses this many P3Cs for the antisubmarine patrol."

It can be said that Japan's antisubmarine patrol P3C capability ranks next to the United States, and that there is a big difference between second and third place. It cannot be said lightly because war potential is evaluated not only by the number of the P3C but also overall fighting strength such as military bases, the number of escort fighters and the war continuation capability. However, if the P3C's antisubmarine patrol is competed like the Olympic games, Japan can take second place for sure. Moreover, Japan may have a chance to win the victory over the United States.

To return to the subject, Fujitsu is largely responsible for this strong capability of the P3C's antisubmarine patrol. The AntiSubmarine Warfare (ASW) P3C is more than an antisubmarine patrol aircraft. The P3C is also a part of the ASW system, and the prerequisite is to have a support system that can effectively develop the ASW. It is called the ASW Operation Center (ASWOC) and it was researched, developed and produced by Fujitsu in cooperation with the MSDF.

It can be said that without the ASWOC Japan would have had neither P3Cs for ASW nor sealane defense based on the U.S.-Japan Security Treaty. And the ASWOC apparently has had significant impact on Fujitsu's future as well.

Fujitsu Advanced Into Defense Area at One Word From Former President

The history of the defense technology of Fujitsu is still short. A new factory of Fuji Communications Equipment Manufacturing Co. was constructed at Nakahara-ku, Kawasaki-shi in 1938 where the Fujitsu's Kawasaki Plant is located at present, and it has been delivering a little radio communications equipment to the Defense Agency since the Self-Defense Force was established after the war. It changed its name to Fujitsu in June 1967 and merged with Kobe Kogyo Co. in July 1968. Kobe Kogyo was also conducting the research on radars and infrared rays, etc.

After that, Fujitsu made marked growth, and its sales in the field of computers in 1979 became top in the industry beating IBM Japan. It succeeded in the business of word processors and personal computers after that, but it was in January 1981 when Fujitsu decided to positively participate in defense technology.

At this time, the Fujitsu System Integrated Laboratory (FSI) was established in its Kawasaki Plant. At that time Daisuke Kobayashi was the eighth president and Takuma Yamamoto (the present president) was managing director. Some opposed the full-scale participation in the defense industry at that time, but President Kobayashi made a decision. Kobayashi said, "You cannot expect immediate profits from the defense business. Let's tackle the technical development with a long-term view by taking different measures from other business departments of Fujitsu." The ASWOC is also one of the results, but its details will be mentioned later. The relation between Fujitsu and defense technology will be stated in the following.

Yamamoto became the ninth president of Fujitsu. He was graduated from the Military Academy, and was a pilot of the "Hayabusa" fighter. In 1949, after the war, he entered Fujitsu after graduating from the Engineering Department of Tokyo University. President Yamamoto's career might have had a great connection to his enthusiasm for the defense industry.

The Special Equipment System Headquarters was established in July 1987, and the Defense Business Headquarters was in charge until that time, but its business was limited mainly to sales. The new Special Machine System Headquarters (SMSH) is an organization that changed the old standard and included part of the Fujitsu System Integrated Laboratory.

Akihito Morita, chief of the Headquarters Business Promotion Department, explains the circumstances: "We would direct our efforts toward the development of communications and information systems of the future defense technology. But since we have accumulated technologies as our basis, we thought that we had better not limit our business only to 'defense sales,' and the Special Machine System Headquarters was inaugurated to integrate the technologies."

"The Special Machine System" was established around this time, which is for the maintenance and repair of equipment and systems delivered to the Defense Agency (DA).

Then, "Fujitsu Defense System Engineering" was newly established in July 1988. Once Fujitsu established guidelines that directed their defense technology toward communications and information related systems, their software development capability naturally became a significant factor. It has two purposes.

First is to cope with the quantitative expansion of manpower for the development. The number of personnel of the development department of the SMSH was increased, but the securing of personnel who could catch up with the accumulation of know-how and development was becoming difficult. It meant that Fujitsu's enthusiasm toward defense technology and expectation toward its growth rate were large, but in reality, they had to face the shortage of manpower. This problem is not limited to defense technology. For example, the number of college-graduates newly recruited by Fujitsu for this fiscal year is about 1,300 (3,000 if high school graduates are included), and the number becomes as large as 8,500 if about 60 affiliated companies are added. The FSI, which was established first, is still in operation, conducting software and hardware R&D for the Defense Agency with emphasis on long-term perspectives.

President Toshimichi Suzuki was in an important position as chief of staff of the Ground Self-Defense Force (GSDF).

Second is to acquire particular military know-how in the area of defense technology and prevent technology leaks to outsiders. One of the objectives is "to observe secrecy." Compared to Mitsubishi and Kawasaki Heavy Industries, who have been engaged in the military business since before the war, Fujitsu's history of participation is rather short. However, Fujitsu has caught up fast enough already to require a corporate proprietary system.

Understanding Technical Terms Was Difficult in the Beginning

We asked Ichiro Nakajima, chief of the System Development General Management, SMSH, why Fujitsu leaned toward the development of the ASWOC.

The center of the military technology from now on is the R&D of command, control, communication and intelligence (C3I) as systems. The United States is most advanced in this field, and Japan's Self-Defense Force is also putting great emphasis on it. "Suppose the enemy has 1,000 tanks, but they only have telephones for their mutual communications. And we only have 100 tanks, but if our combat information processing, the commander's orders, etc., are systematic and fast, we have the possibility of beating the 1,000 tanks. It depends on how we use our resources (resources and capacity). It is the air defense system BADGE or the ASWOC of the P3C of the Air Self-Defense Force (ASDF). We were confident that we could fully utilize the capacity of Fujitsu in the development of these."

The ASWOC is a system that supports the operation of the P3C on the ground. For example, a captain or a formation chief will give a preflight briefing to the crew (10 in a plane) of the P3C before taking off from the air base. An explanation is given in the operation room using a screen, and the pretape recorded data are input in the computer of the aircraft. While in flight, collected ASW data are transmitted to the ground by voice, teletype and data link. The ASWOC sends back the data after analysis and transmits the order of the commander on the ground. When the P3C returns to the base, the information on the submarine is analyzed and reevaluated.

In an antisubmarine operation, even an expert crew mistakes the sound of a whale for that of a submarine, therefore, identification of fine data is indispensable. For example, like the fingerprints of 2 billion people vary by little, even the same type submarine produces a little different sound. This sound is used as the data for identification like a fingerprint, and this is "top secret" information even for the United States, an ally of Japan. Constant information collection and analysis is prerequisite for the ASW.

In short, the ASWOC is for the effective operation of the system of the P3C. In the development of the ASWOC that began in 1981, the MSDF purchased basic software from the U.S. Navy first, but this was limited strictly to basic technology and Fujitsu did its utmost to complete the ASWOC for the MSDF. Since the P3C was meant for military rather than civilian use, Fujitsu's systems engineers always had to work together with the pilots, strategists, etc. Toshikatsu Kikuchi, chief of the Second Development Division, System Development General Management, looks back and says, "It was a lot more difficult work than to produce the weapons such as the F15 fighter or the P3C antisubmarine patrol plane almost completed in the United States, but it was rewarding work."

"In the beginning, sometimes we could not communicate with the DA. They did not understand the technical terms of computers, and we could not figure out 'Tako' at the study meeting with MSDF pilots. It was an abbreviation for the tactical officer (TACO) who controls the ASW on the P3C. But it was a pleasure for engineers to develop what people operating the P3C actually needed. Fujitsu has always excelled in its ability to apply users' demands to their systems."

The ASWOC is something like a decision-making system in the private sector, but no system whose performance is as high as the ASWOC has been realized in the private sector. Kikuchi said, "We put what we had never experienced to practical use. Moreover, there was a time limit that the P3C was actually to be deployed in the field by April 1982. Concentration of the efforts of respective departments of Fujitsu for the completion of the ASWOC produced good results."

Fujitsu learned a lot in the process of developing the ASWOC. Since the ASWOC computers are for military use, they must be operated for 24 hours. Not only were two computers set up but there was also a spare ready to go at all times. The ASWOC was constructed at various airbase regions such as Atsugi, Hachinohe, etc., (where the P3Cs were placed) and service personnel were permanently assigned to the Hachinohe Branch.

The cost of an ASWOC system is about ¥5 billion, and its construction is scheduled at Kanoya Air Base in the future. Further, the ASWOC control terminal was also completed at the Fleet Air Force Headquarters at Atsugi

in June last year. It exercises general control over each air base of the P3C. This is a system unique to Japan that even the U.S. Navy does not possess.

Delivery of the ASWOC has meant more to Fujitsu than the profits derived from the venture. The military technologies of the United States and the Soviet Union are progressing rapidly and competing severely, and the P3C is also constantly being improved from "Update 2" to "Update 3." It is said that Fujitsu's ASWOC is the "Update 2 plus 1/2." Fujitsu employees have benefitted from a new source of energy generated by enthusiasm not usually found in the private sector working environment.

Absolute Challenge Even If It Meant No Profit

On the other hand, the contracts with the DA other than the ASWOC are as follows.

GSDF: The firing control system of the short-range antiaircraft missile (Short SAM) (March 1982 -). The fighting training system (March 1986 -).

Although the main contractor of the short SAM is Toshiba, the device that detects and chases the target with infrared rays, that is the eye of a missile, was manufactured by Fujitsu.

Fujitsu already manufactured an infrared sensor about 1972, and it is proud of being at the top in the industry in the development of the element whose sensitivity is best at normal temperature.

There are two methods employed in the target chasing of a missile: radiowave homing and infrared homing. Infrared homing has characteristics such as the following: 1) Target searching time is short; 2) target identification capacity is high (the temperature of military aircraft, warships, tanks, etc., is generally high, therefore, high-constant images can be obtained by utilizing infrared rays); 3) different from radiowave, it is difficult for the enemy to disturb.

MSDF: P3C antisubmarine patrol plane mounting electronic equipment (May 1982 -). ASWOC (March 1982 -). Ship mounting radiowave jamming device (March 1983 -).

ASDF: Fighter mounting radiowave jamming device (March 1975-). Electronic warfare capacity evaluation system (March 1989 -).

One notices from the above that much of Fujitsu's defense technology is connected with electronic warfare. The electronic warfare capability will become the key to military strength in the future together with the C3I. JASDF's Chiefs of Staff have insisted in the past that "No matter how great our fighters, missiles and radars may be, they are simply toys as long as our electronic warfare capability is inferior." Because if radiowaves are jammed by the enemy and we have no countermeasures, the radar scope would become white and our missile would fly in a wrong direction. Moreover, electronic warfare information is top secret also for the United States, and they will never easily release it to us. Japan must conduct its own development in this area.

Radiowave jamming devices for fighters are the ALQ6 of the F4 Phantom and the ALQ8 of the F15 Eagle, and they are useful weapons because they divert the enemy's radiowave homing missiles by jamming their radiowaves. The electronic warfare evaluation system is scheduled for completion at the Air Experiment Wing in the Gifu Air Base by March next year, and it is something like a huge "darkroom." The F15 fighter, etc., are placed in this and the testings of the operation of the radiowave jamming device, etc., are repeated. Several years ago, when we inspected the "electronic darkroom" of Grumman Co., we were told that, "The F14 Tomcat is tested in this room. If the same test were conducted in the air, no televisions in New York and Washington could be watched because of the disturbance."

According to the ranking list of the amounts of contracts published by the Procurement Headquarters of the DA, Fujitsu was in eighth place with 164 contracts amounting to ¥22.273 billion in FY87. Fujitsu's place has risen from 19th in FY84 to 13th, 12th, and 8th place, respectively. There are, of course, its rivals Mitsubishi Electric (third place), Toshiba (fifth place), and NEC (sixth place) in higher ranks.

Chief Morita of the Business Promotion Department is very enthusiastic about the fields Fujitsu will pursue in the future saying, "Fujitsu's sales to the DA is only a little over 1 percent of the entire sales by Fujitsu, but products are not color coded (not territorial) in the electronics or avionics industrial circle."

One of the examples is the air-to-ship missile ASM2 that the DA will develop next. Although its main contractor is Mitsubishi Heavy Industries, Fujitsu was selected as contractor for the development of its infrared sensor, the eye of the missile, over Mitsubishi Electric, Toshiba, and NEC. The infrared sensor is the image homing device that catches the image of the target with infrared rays and hits the target. The enemy's warship also shoots heat generating objects and cheats the infrared sensor. The image homing, however, memorizes the image of necessary targets such as the enemy's cruiser, and the ASM2 will proceed to the point where the image and that of the infrared sensor meet. And the missile will hit the target without being fooled by decoys. Japan's high technology, especially the one of Fujitsu, is highly evaluated also by the United States.

Fujitsu very recently decided to increase the personnel of its subsidiary company "Defense System Engineering" from 45 to 250 over 3 years. President Yamamoto once emphasized, "Fujitsu advanced to the area of computers from that of communications, and its enterprise status was established. It should further contribute to the defense area as an enterprise. We will firmly challenge the defense technology even if that means no profit for the time being." Fujitsu is on the right track at last. It may be said that it started by the top-down method, but it is flowering from the bottom up.

Small Synchrotron Radiation Light Source Developed

43063542 Tokyo JITA NEWS in Japanese Apr 89 pp 11-15, 18

[Article by Takio Tomimasu, chief, Quantum Radiation Division, Electrotechnical Laboratory, Agency of Industrial Science and Technology: "Laboratory Highlights: Development and Application of Small Synchrotron Radiation Light Source"; first paragraph is JITA NEWS introduction]

[Text] This article consolidates the author's research, which was commended by the minister of international trade and industry in the ceremony of 7 November last year commemorating the 40th anniversary of establishment of the Agency of Industrial Science and Technology.

1. Synchrotron Radiation and Small Radiation Light Source To Be Developed

Electromagnetic waves generate when electrons move in such ways as circulation, meandering, and vibration by the magnetic field, etc. The wavelength, directivity, and intensity of electromagnetic waves generated greatly vary by the velocity of electrons, the magnetic or electric field, and the conditions (vacuum, gaseous/liquid/solid, etc.) of the place in which the electrons are in motion. Synchrotron radiation (abbreviated as SR; in Japan, it is also referred to as radiation light or synchrotron orbital radiation, abbreviated SOR) is intense white light with sharp directivity that is generated when, as indicated in Figure 1, an electron beam accelerated approximately to the velocity of light is deflected by a magnetic field in an extra-high vacuum. Photo 1 [not reproduced] is a photograph of SR from the Electrotechnical Laboratory's 800 MeV electron accumulation ring (TERAS) and shows the sharp directivity of SR.

Electrons were discovered in 1897. Then, it was theoretically learned that charged particles generated electromagnetic waves when they made circular motion or vibrated.[1] Magnetron and other microwave sources have been developed on the basis of this theory but it was from G.E.'s 70 MeV electron synchrotron that artificial SR was first observed.[2] Since the doughnut-shaped vacuum container in which electrons circulated was a glass product, light radiated by the electrons (visible light of SR) could be easily observed and it began to be called synchrotron radiation.

SR is generated by the same principle as medical X-rays are generated and microwaves by the electronic range magnetron are generated but the conditions of SR generation are that it is generated in a vacuum and that β = v/c equivalent to 1, v perpendicular v (derivative) where c is the velocity of light, v is the velocity of electrons and v (derivative) is acceleration. As indicated in Figure 1, the vibration components of electrons are produced by acceleration in a direction at right angle to the course (v perpendicular v (derivative) and the electromagnetic

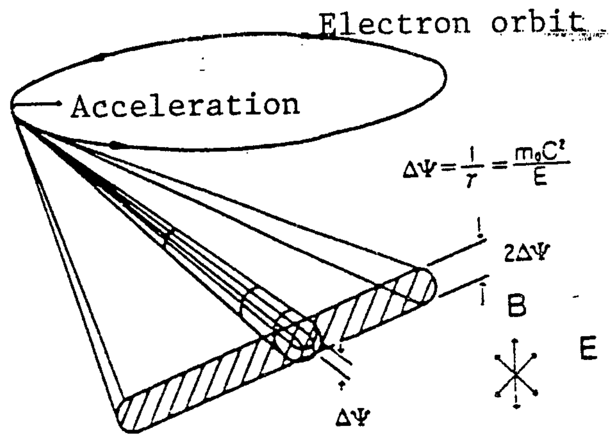


Figure 1. Directivity of Synchrotron Radiation (SR)

waves generated by this vibration have excellent characteristics lacking in conventional light sources. They are:

a. The divergent angle becomes about by the relativity effect and diminishes at v/c equivalent to 1 (sharp directivity);

$$\sqrt{1 - v^2 / c^2}$$

b. Since the vibration frequency becomes 1/(1-v/c)-fold by the Doppler effect, the spectral distribution extends as far as the X-ray domain (high energization, continuous spectrum);

c. In a high-energy electron beam with a luminary point of only about 1 mm in diameter, the radiant power is proportional to the fourth power of electron energy E. Thus, SR becomes highly bright light of four digits or over, compared with the conventional light source (attainment of high brightness);

d. The high-energy electron beam serving as the light source is discarded in an electronic synchrotron as waste heat but in an electronic accumulation ring, it can be efficiently used by circulating it about a trillion times in a doughnut-shaped super-high-vacuum tank while supplying SR with lost energy in an accelerated cavity. Hence, the possibility of attaining a high output (attainment of high output).

In the generation of diagnostic X-rays, for example, X-rays—unlike SR—generate in the metal, light and soft X-ray components are absorbed and v/c = 0.4-0.7 and, therefore, the divergent angle of X-rays is about 0.9-0.7 rad. In the X-ray plant, fast electrons are pulled, as in Figure 2, by attraction working between it and the atomic nucleus of the heavy metal and thus the orbit bends. At the time, part of the electronic energy is radiated as visible light or X-rays, since X-rays with a short wavelength can be produced if the orbit of electrons is sharply bent with strong attraction. Thus, in the X-ray apparatus, the coulomb working between the +Ze

of the atomic nucleus and the electron is increased by using a heavy metal with a large atomic number (Z) as the target irradiating electrons. By this method, as indicated in Figure 2, electrons bend variously (in the case of SR generation by an accumulation ring, the electronic energy is constant and the manner in which the electronic orbit bends is also constant) and the electronic beam injected into the target, the visible light generated in the target, and soft X-rays of about 1 nm useful for extra super LSI lithography are absorbed in the metal target and achieving a high output is difficult because of the difficulty of removing the waste heat. Consequently, X-rays from an X-ray plant greatly differ from SR in directivity and intensity.

The upper limit of output of the conventional laser is decided by the efficiency of removing waste heat from the exciting substance. It is because of its high efficiency in this waste heat removal that the free electron laser using a high-energy electron beam is expected to have a larger output than the conventional laser.

An accelerator is used to accelerate electrons approximately to the velocity of light. As accelerators of electrons and ions, there are those of the accelerating formula by the constant electric field between electrodes in a high-vacuum container, as in the Braun tube television set, and those of the accelerating formula by the high-frequency electric field generated in a high-frequency accelerating cavity electrode tube, as in the accumulation ring. In the ring, the chances of acceleration become high-frequency periods because, in it, the intensity and direction of the electric field change with time. As in Figure 3 where the ring's deflecting electromagnet and converging quadruple electrodes electromagnet and the doughnut-shaped vacuum tank are omitted, the electron beam accelerated in the ring can be presented graphically as acceleration of pulse beams arranged at high-frequency wavelength intervals. Energy lost through the radiation of SR by electrons can be compensated by the high-frequency cavity. hyperfine pattern transcription with a 0.25 μm line width, which is impossible with conventional light sources, and as an X-ray source for

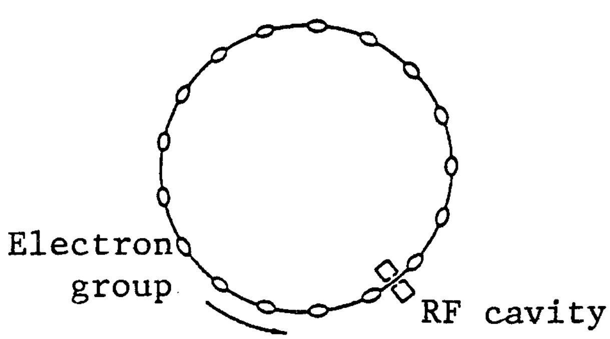


Figure 2. Electronic Group Circling at Equal Intervals and Synchronously With Electrical Field of SR Cavity

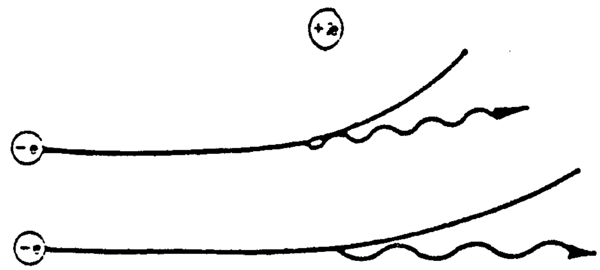


Figure 3. Generation of X-Rays by Fast Electrons in Metal

photographing cardiac capillaries, thus contributing much to the treatment of such diseases as cardiac insufficiency. But it has had shortcomings, such as a field of

SR is more than four digits as bright as conventional light sources and excels in directivity and can, therefore, have many applications from X-rays to infrared rays. Thus, it is expected to be most useful as a light source for lithographical purposes, including the 256 Mbit DRAM irradiation that is too narrow due to its sharp directivity to be used for large-area irradiation on the silicon wafer or the heart and an SR-generating electron accumulation ring that is, as it is, too large to be installed at a semiconductor plant or a hospital.

When the Electrotechnical Laboratory moved to Tsukuba, it tentatively produced the nation's first regular lithographical electron accumulating ring, TERAS,[5] and an efficacy electron linear accelerator capable of injecting electrons into the accumulating ring,[6] working on its own accelerator technology.[3,4] Though little known, we authors devised the disk pore diameter constant gradient accelerating tube.[3] About 200 of these tubes have been used as electron injector for the photon factory of the High Energy Physics Laboratory.

In the Electrotechnical Laboratory's development of a small SR light source and research on its application, a new area of SR technology was opened by discovering the wave characteristic[7] of the electron beam in an accumulation ring, taking advantage of the above-mentioned technologies, and inventing an electron wave ring[8-13] capable of large-area SR irradiation for the silicon wafer and the heart and, at the same time, completing the world's first small ring, NIJI-I,[14,15] and establishing the electron wave process indispensable to the miniaturizing of SR light sources and the technologies of low-energy electron incidence and large current accumulation. Developing light sources according to purposes shown in Table 1 is possible by the technology devised by this laboratory as indispensable to the miniaturizing of SR light sources. Also possible are the development of new industries, including an LSI industry, the generation of free electron laser, and new research concerning the standards for electric current and light.[16]

Table 1. Small Radiation Light Sources To Be Developed

Light source performance	Purpose of use
Small industrial soft X-ray (equivalent to 1 keV) ring. Large-area irradiation for silicon wafers is possible by a small electron wave ring with an outside diameter of less than 5 m.	For ultrahigh lithography. Submicron line width pattern transcription light source. Ec (keV) = 2.218 x E^3(GeV),/R(m)
Electron energy equivalent to 1 GeV, accumulated current equivalent to 300 mA. Small medical X-ray (equivalent to 33 keV) ring. A wiggler driven by superconductive pulses is inserted into the straight part of an electron wave ring with an outside diameter of about 10 m. It is so small that it can be used to photograph blood vessels in such visceras as the heart. Electron energy 1.5-2 GeV, accumulated current 500 mA.	Exclusively for medical and diagnostic use. Angiographical light source using the iodine absorbing end (33 keV). Ec (keV) = 0.664 x E^2(GeV) x B(T)
Small ring for free electron lasers. An optical klystron is inserted into a long straight part of 5 m or more in a racetrack shape. Use of a large-output wavelength laser for CVD. Electron energy equivalent to 0.5 GeV, accumulated current 300 mA.	Use for processing CVD, etc. Ec (keV) = 0.948 x E^2(GeV)/[λ_0(cm) x $(1+k^2/2)$]

2. Properties of SR[17]

When electrons proceeding at a velocity close to the velocity of light are accelerated in a direction at right angle to the direction in which they are proceeding, they have the characteristic of a bright light source in that the electromagnetic waves they radiate (SR) have sharp directivity and wide spectral distribution due to relativity and Doppler effects. These properties of SR may be consolidated as follows:

a. Sharp directivity

Using E for the total energy of electrons and moc^2 for their rest energy, $\Delta\psi$, the angle of divergence of SR, decreases by the relativity effect proportionally as their energy is large and the field of irradiation shown in Figure 1 as a slash-lined section is narrow in the vertical direction and flat with sideway length.

$\Delta\psi = 1\text{-}v^2/c^2 = moc^2/E = 1/\gamma$ (1)

b. Continuous spectrum with wide wavelength range

Electromagnetic waves are generated by the vibration component resulting from the deflection of fast electrons and the number of vibrations of the electromagnetic waves is $1/(1\text{-}v/c)$ times by the Doppler effect and, therefore, they have a wide spectral distribution reaching the X-ray domain and Ec, characteristic energy of SR, is:

E_c(keV) = 2.218 E^3(GeV)/ρ(m) (2)

If, for example, E = 6 GeV, ρ = 20 m, E_c = 24.0 KeV.

c. Bright light source with large irradiance

ΔE, energy lost by electrons with energy E(GeV) as they make a round of a ring with an orbit radius of ρ(m), is:

ΔE (keV) = 88.47 E^4(GeV)/ρ (m) (3)

Using I(A) as the average current of the electron beam, P(kW), total radiation power of SR, is:

P(kW) = 88.47 E^4(GeV) I(A)/ρ (m) (4)

If, for example, the energy is 1 GeV, the current is 0.3 A and the orbit radius is 2.8 m, the total radiation power is 9.5 kW.

N, number of photons, can be obtained by dividing P in Expression (4) by hc/λ, photon energy. N, number of photons radiated every second per mrad of the horizontal angle of the electron orbit and per 1 percent wavelength width (λ/λ) by an electron beam with relative energy and a current of I(A), can be obtained by the following expression.

N = $P\lambda/hc = 1.256 \times 10^{11}\lambda$ I(A) $G_1 = \gamma$ I(A) $F(\lambda/\lambda_c)$ (5)

Figure 4 shows the function $F(\lambda/\lambda_c)$ for the wavelength dependency of the number of photons.

d. Deflected vibration plane of light

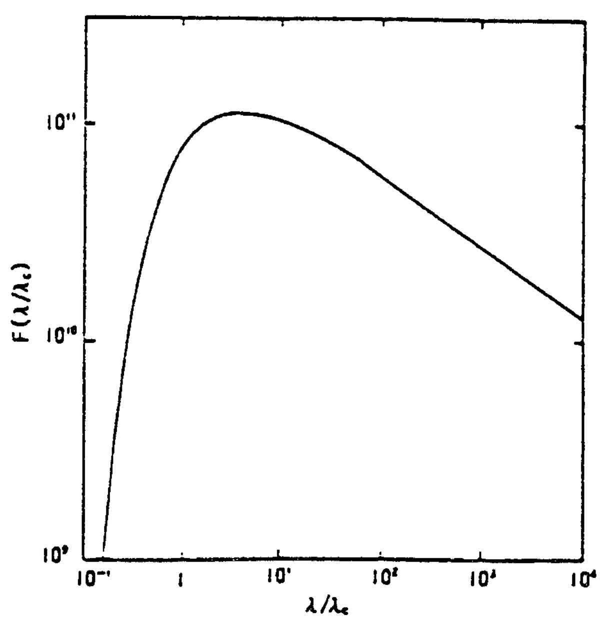


Figure 4. F(/$_c$), Function Showing Wavelength Dependency of Number of Photons

Mchine and Location	Size(m)	E(GeV)	R(m)	I(mA)	Ec(eV)
COSY− I (Berlin, BESSY)	~ 2 ϕ	0.56	0.37		1053
COSY−II (Berlin, BESSY)	~ 6 × 2	0.63	0.44	50	1260
MARS (? , NEYRPIC)	5 ϕ	0.8	1.6		710
IBM (? , OXFORD, INSTR)	~ 6 × 2	0.7	0.52		1463
SXLS (Brookhaven, BNL)	~ 5 × 2	0.68	0.568		1224
TERAS (Tsukuba, ETL)	10ϕ	0.8	2.0	250	568
NIJI− I (Tsukuba, ETL-SEI)	4 ϕ	0.27	0.7	524	62
NIJI−II (Tsukuba, ETL-SEI)	5 ϕ	0.6	1.4		342
NIJI−III (Tsukuba, SEI-ETL)	~ 4 ϕ	0.62	0.5		1057
SORTEC− I (Tsukuba, SORTEC-ETL)	15ϕ	1.0	2.8		792
NTT− I (Atsugi, NTT-Toshiba)	~17ϕ	0.8	1.85	25	614
NTT−II (Atsugi, NTT-HITACHI)	9 ×2.5	0.6	0.67		715
AURORA (Tanashi, SHI)	3 ϕ	0.65	0.5		1218
LUNA (Tsukuba, IHI)	6.8	0.8	2.0		568
JSR (Tokai, JAERI)	~ 6 Δ	0.3	0.835		72

Regarding SR radiation onto the orbital plane ($\psi = 0$) of electrons, linearly polarized light with an electric vector parallel to the orbital plane can be obtained. Also, polarized light above and below the orbital plane is elliptic to an extent depending on angle of openness ψ.

e. Pulse light source with a fast cycle period

As indicated in Figure 3, an electron group (bunch) is synchronized with the accelerated electric field of an acceleration cavity and circles at equal intervals. Therefore, SR is a pulse light source. In the case of 162.1 MHz, the punch interval is about 6 ns and the punch length is about 0.5 ns, depending somewhat on the accumulated current.

3. Present Status of Development of SR Light Sources in Japan and Abroad

At present, there is a world total of 23 SR light sources exclusively for the use of radiated light and an additional 10 or so are being constructed or developed. What is already in operation is used mainly for the analysis or evaluation of materials by photoelectronic spectroscopy, EXAFS, etc. As listed in Table 2, 15 for extra super LSI's with submicron stroke widths are in operation by small rings or being constructed. None exclusively for medical use are yet available. Of the above, TERAS (1981) and NIJI-I (1986) of the Electrotechnical Laboratory, COSY-II (normally conductive type; 1986) of BESSY and NTT-I (1986) and NTT-II (1989) of NTT are in operation. However, the accumulated current for NTT-II has yet to be announced. With the exception of TERAS of the Electrotechnical Laboratory, all are rings aimed at lithography and it is interesting to note that the time of completion of all is concentrated on 1989-1990, which is about a year before the tentative manufacture of the 64 bit DRAM.

NIJI-I, the first small ring to operate,[14-15] was developed jointly by the Electrotechnical Laboratory and Sumitomo Electric Industries and proved for the first time anywhere in the world that low-energy large-current accumulation by 524 mA at 160 MeV is possible. Thus, it brought the bright prospect of miniaturizing SR facilities. By the end of 1989, the normally conductive 600 MeV ring NIJI-II and a superconductive 620 MeV ring will be completed by Electrotechnical Laboratory/ Sumitomo Electric Industries, a superconductive 650 MeV ring by the Sumitomo Heavy Industries, and a normally conductive 800 MeV ring by the Ishikawajima-Harima Heavy Industries. Abroad, COSY-II of BESSY in West Germany has been put into operation by a normally conductive ring, small superconductive rings have begun to be constructed by BNL and IBM in the United States while Bechtel and Westinghouse have begun to note miniaturization research, sending their men to investigate our small rings. Though America has thus become active, Japan nonetheless leads the world in the development of small rings.

4. Electrotechnical Laboratory's Research on the Miniaturization of SR Light Sources

4.1 Direction of Miniaturization

Many of the small rings shown in Table 2 are being developed as light sources for the extra super LSI lithography (line width: 0.25 μm) of several years hence. But what is now noted along with lithography is angiography or the photography of heart capillaries by wiggler X-rays which excel in directivity and are energy-variable. This is an attempt to prevent cases of people in their thirties and forties dying of acute cardiac insufficiency as their vasoconstriction progresses without subjective symptoms. To develop an angiographical diagnostic system for the coronary artery system of the heart, the X-ray ring must be miniaturized to the hospital scale.

As is clear from the foregoing explanation of the properties of SR X-rays and the SR spectrum in Figure 5, an accumulation ring capable of producing SR with the greatest content of X-rays of about 1 nm suitable for lithography with a line width of 0.25 μm has an electron

energy of 0.8-1 GeV and an orbit radius of 10 m or more in the normally conductive form and, when a vacuum beam line using SR is added, the whole SR apparatus is as large as $25m^2$, at the least. Reducing this to $12m^2$, as in Figure 6, is the target of the basic research of the small SOR apparatus by a government/private solidarity joint research system to which the Electrotechnical Laboratory is central and the target of the Research Development Corporation of Japan's commissioned work to develop a small X-ray exposure electronic wave ring based on the results of the author's research on the electronic wave process (commissioned to Sumitomo Electric Industries).[18]

In a ring capable of emitting radial light that can be used for medical diagnosis or the treatment of cancer, electron energy is 6 GeV or more and the electronic orbit radius is 20 m or more in the normally conductive type, as can be seen from the SR spectrum (2) expression in Figure 4. As long as a normally conductive electromagnet now

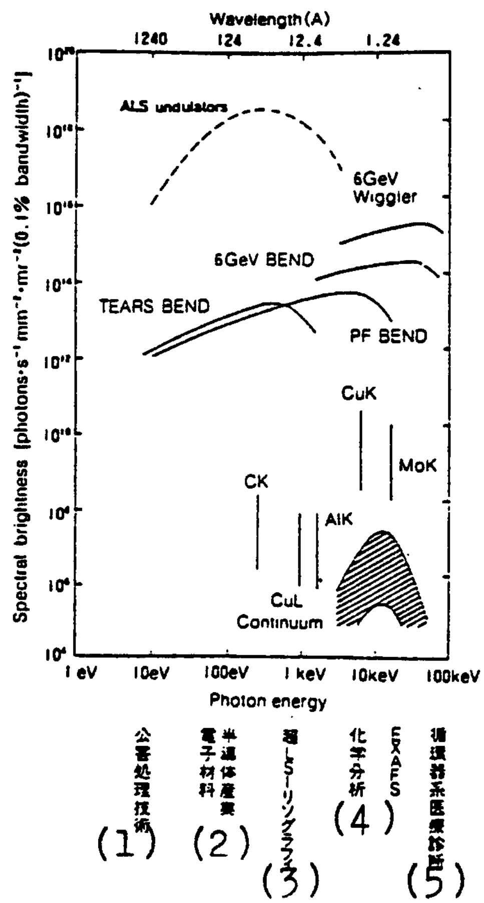


Figure 5. Spectral Distribution of SR and Main Applications

Key:—1. Pollution treating technology—2. Electronic material and semiconductor industry—3. Super LSI lithography—4. Chemical analyses—5. Circulatory system treatment and diagnosis

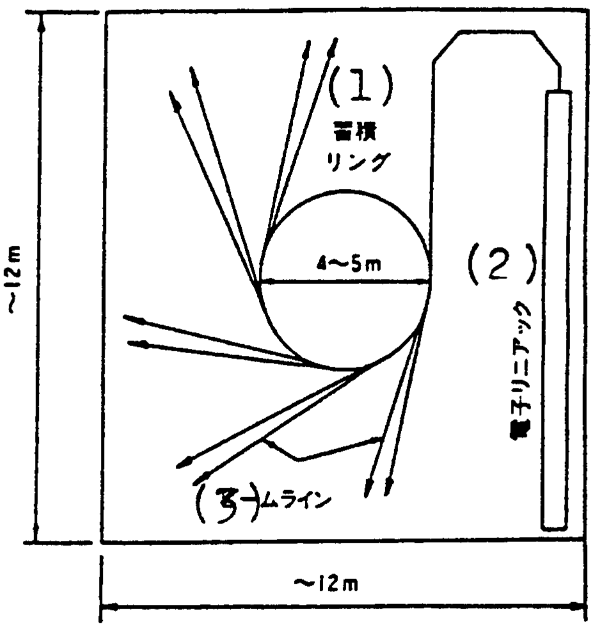


Figure 6. Example of Layout of Small Industrial SR Light Source

Key:—1. Accumulation ring—2. Electronic linear accelerator—3. Beam line

available is used, the average diameter of the ring is nearly 100m and, if the irradiational beam line capable of angiography for the heart is added, the whole X-ray ring will be a super-size apparatus of, at least, 200 m^2.

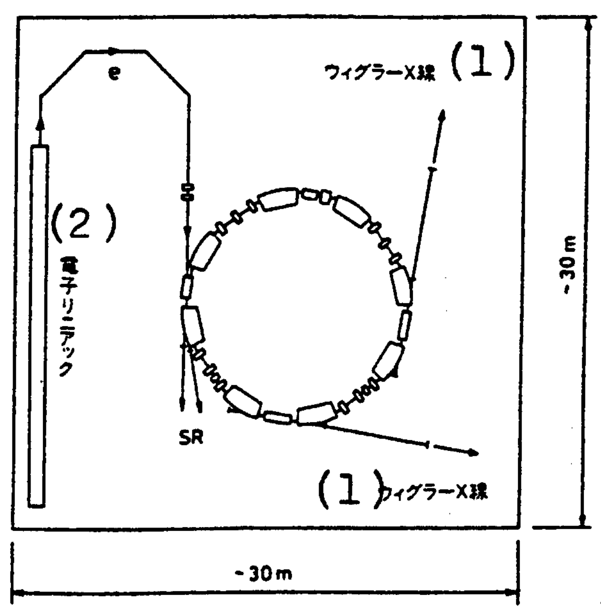


Figure 7. Example of Layout of Small SR Light Source for Medical Diagnosis

Key:—1. Wiggler X-rays—2. Electronic linear accelerator

The aim of the development of the small medical X-ray ring in Table 1 is to reduce this to about 30 m^2, as indicated in Figure 7.[19]

To enable SR X-rays to be used at LSI factories and hospitals, it is necessary to achieve the following in a well-balanced manner:

a) Miniaturize rings (make their radius of curvature small);

b) Be able to practice large-area irradiation, using a short irradiating beam line (measuring only several meters);

c) Miniaturize injectors (practice low-energy, large-current injection);

d) Use a compact shield (low-energy injection, high-efficiency accumulation);

e) Realize high energy for a large-current beam (increase 5-10 times).

For this purpose, the Electrotechnical Laboratory has developed a method to expand the field of SR irradiation by means of electronic waves and a method of low-energy, large-current accumulation of electrons. These are described below.

4.2 Expansion of Field of SR Irradiation by Electronic Waves

As is clear from Table 2, the development of many small rings emphasizes miniaturization through the adoption of superconductivity. But from the point of view of the whole SR apparatus, the effect of miniaturization through the adoption of superconductivity is not great. Rather, reducing the SR beam line to several meters or less while realizing the large-area, equal exposure of SR by the electronic wave method devised by the Electrotechnical Laboratory is much more effective. Figure 8 shows this principle.[5] In SR from the ordinary ring, Gaussian distribution exposure (intensity) measuring only about 1 cm wide in the vertical direction at a distance of 10 m results due to the sharp directivity of SR. But by this method, equal exposure of more than 5 cm (five-fold) has become possible. Also, miniaturizing injectors to several meters, as in Figure 6, is effective.

4.3 Low-Energy, Large-Current Accumulation

Electron injection to an accumulation ring is easiest if electrons to be injected have the same energy as the accumulated energy, as in the case of PF of the High Energy Physics Laboratory or UVSOR of the Institute for Molecular Science. But to miniaturize the SR apparatus, not only the ring but also the electron injector must be small and low-energy, large-current accumulation of less than 150 MeV is desirable for the purpose of also minimizing the generation of fast neutrons when injecting electrons and making radiation shield compact.

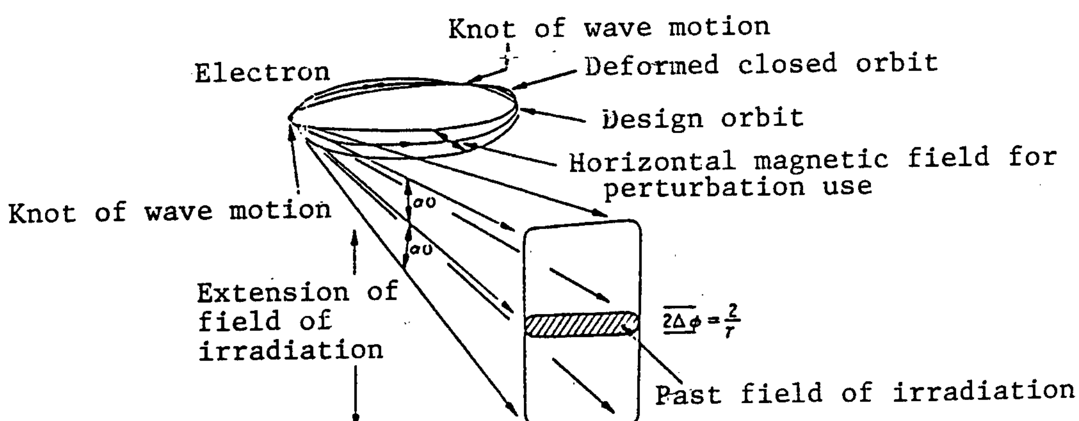


Figure 8. Extension of Field of SR Irradiation by Electronic Wave Method

Temperature, Humidity-Sensing Space-Use Thermistor

43064036 Tokyo SENSA GIJUTSU in Japanese Jun 89 pp 45-47

[Article by K. Ishikawa and T. Hata, Matsushita Electronic Parts Co, Ltd]

[Text] Thermistors being used for Japan's rockets and artificial satellites are imported from overseas countries and, therefore, involve problems in limitations on procurement, delivery, etc. We, therefore, have developed thermistors necessary for the future self-development of H-II rockets and large-sized satellites.

This paper describes the temperature control of the newly developed thermistor and its manufacturing process.

1. Type of Space-Use Thermistor

There are four types of space-use thermistors: negative-characteristic thermistors for temperature compensation, positive-characteristic thermistors for temperature compensation. negative-characteristic thermistors for temperature measurement, and pasting-type thermistors for temperature measurement. Negative-characteristic thermistors account for 9 products whose resistance values and resistance temperature coefficients are different; positive characteristic thermistors, 22 products.

The structure of each type of product is shown in Fig. 1. A semiconductor device is sealed with glass for atmospheric sealing, thus the long-term stability of electric characteristics with emphasis laid on resistance values, is ensured.

To remove adverse effects arising from an inconsistency in thermal expansion between the glass and the device, the positive-characteristic thermistor has been processed to a hollow structure. In addition, the connection between the lead wire and the device and the sealing atmosphere were designed in the following manner:

—Negative characteristic axial: solderless contact, neutral atmosphere;

—Negative characteristic radial: welding, neutral atmosphere;

—Positive characteristic axial: bonding, atmosphere in air.

Thus, the long-term stability of electric characteristics has been improved.

2. Outline of Manufacturing Process and Effect of Temperature/Humidity

An outline of the manufacturing process has been shown in Fig. 2. The following processes are greatly affected by temperature and humdity.

—Device process: Baking, annealing, electrode.

—Assembling process:

Positive characteristic thermistor: Bonding and baking of lead wires, glass sealing;

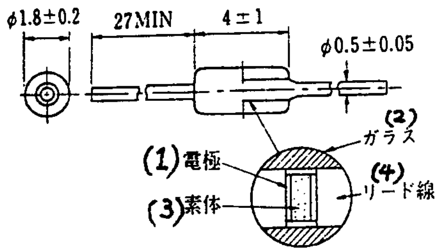
Negative characteristic thermistor: Glass sealing (solderless contact between device and lead wire), embedding of glass.

[]MResistance value selection and inspection process: Common process.

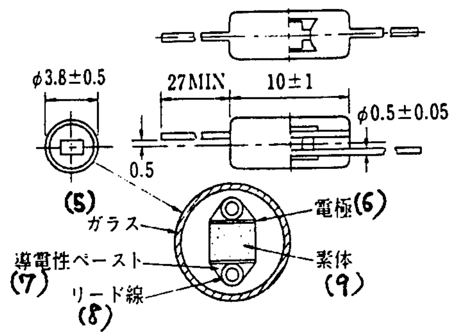
As an example, the relation between temperatures and characteristics is shown in Figure 3 for the baking process. The figure shows that the characteristics of the positive-characteristic thermistors are stabilized by annealing after baking. Raw materials and parts are stored at room temperature under dehumidified conditions to prevent them from deterioration arising from moisture absorption or adsorption of carbonic acid gas and hydrogen sulfide. In the glass-sealing process of the assembling process, the glass-sealing temperature plays an important role in properly carrying out sealing. Glass sealing is properly carried out by ensuring bonding between the metal lead wires and the glass. The wetting angle of Dumet lead wires and glass with respect to the glass-sealing temperatures and changes in resistance at high temperatures are shown in Figures 4 and 5. These figures allow an optimum sealing temperature to be determined. The tolerance in resistance is 1 percent at the resistance value selection process, which is about 0.3°C in terms of temperature. Thus, resistance values having a narrow temperature tolerance are selected and, therefore, a temperature accuracy (for resistance value selection) of 0.04°C has been secured within a range from -50°C to 150°C. A relation between temperature accuracy and resistance value errors is shown in Figure 6. In measuring resistance values, such errors in temperatures are incorporated. Furthermore, procedures have been established to ensure that resistance values are measured in such a way that the temperature instrument indications fall within 0.005°C.

3. Sensor Selection Points in Temperature/Humidity Control and Measures for Optimum Control

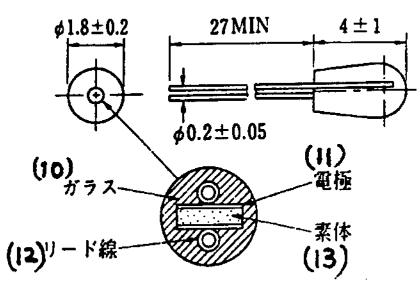
The thermistors herein referred to are not mass-produced and, therefore, the temperature of thermistors is raised or lowered from the room temperature according to the processing temperature at the manufacturing processes. Consequently, the same sensor must cover a wide temperature range. It is required, therefore, that the thermistor indicate a performance reproducible for a long period of time without hysteresis errors and that matching with measuring instruments and controllers can be readily carried out with good accuracy during inspection, repair and replacement. Functions required for sensors and the corresponding sensors are arranged in Table 1. Further, in the baking process, which greatly affects the ceramics performance, Seger cones, etc., are used for heat-value control. With regard to temperature-detection-control input values, output values are checked and confirmed and the redundancy of heat- value control is increased. Furthermore, in the process for measuring resistance values (the most important values as



Negative Characteristic Thermistor for Temperature Measurement (THR03)



Pasting Type Thermistor Temperature Sensor (THR51)



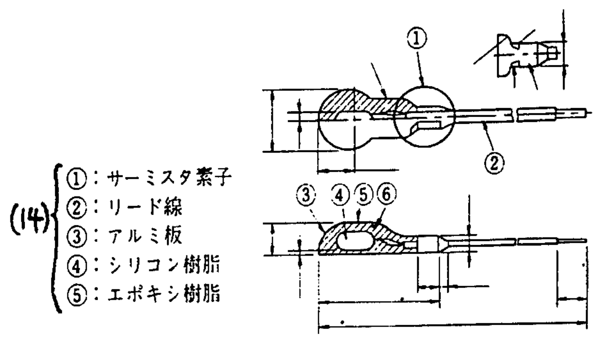


Fig. 1 Space-Use Thermistor Structure

Key:—1. Electrode—2. Glass—3. Device—4. Lead wire—5. Glass—6. Electrode—7. Conductive paste—8. Lead wire—9. Device—10. Glass—11. Electrode—12. Lead wire—13. Device—14. (1): Thermistor element (2): Lead wire (3): Aluminium plate (4): Silicon resin (5): Epoxy resin

characteristics), a standard sample having the same shape and dimensions as those of the item to be measured is measured and checked, in addition to measurements using a temperature sensor. Such sample is used as an auxiliary means for temperature control including temperature distribution in the measuring tank and the ability to follow temperature control. Thus, measures are established to ensure that the measuring accuracy can be enhanced.

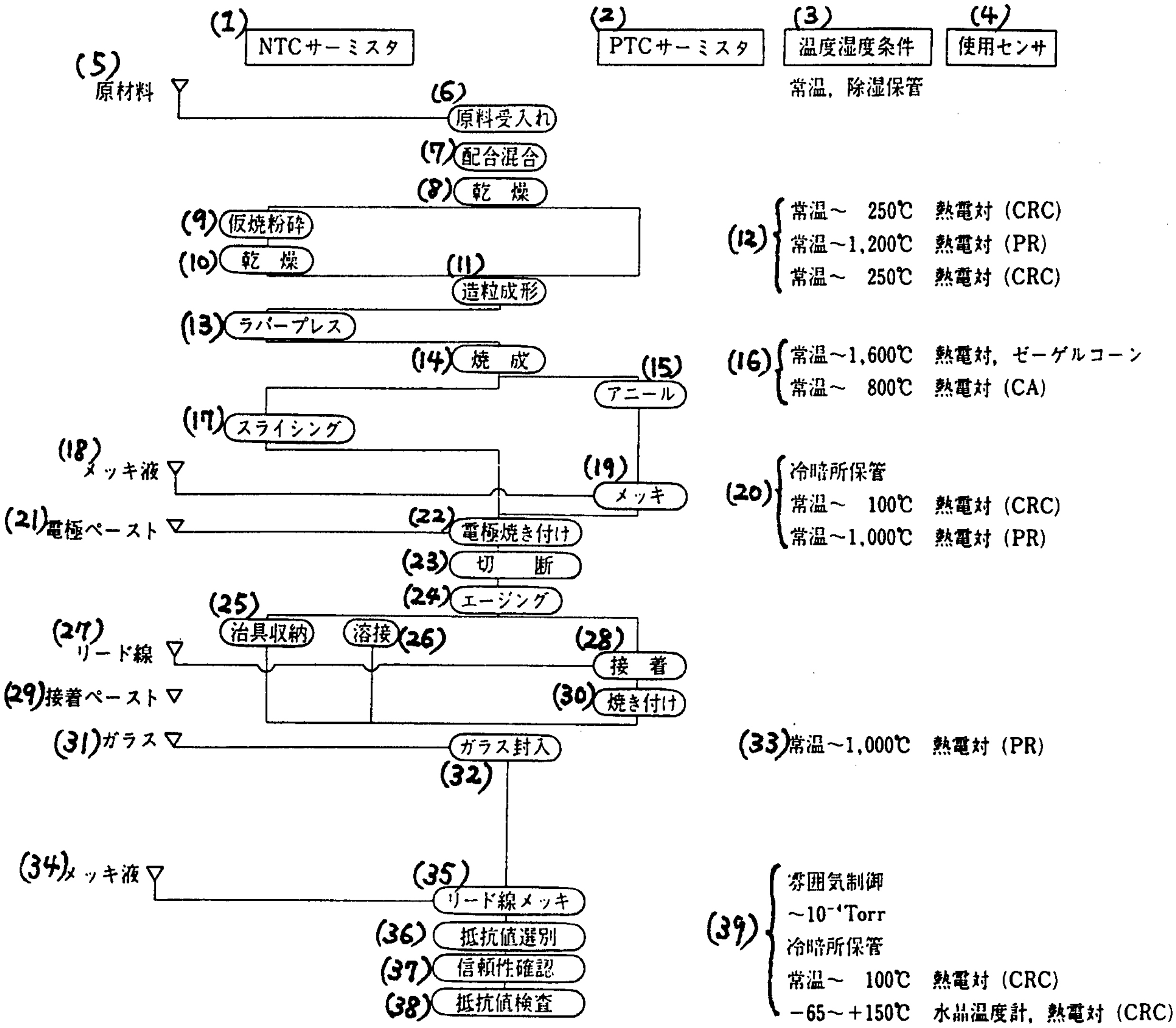


Fig. 2 Manufacturing Process and Temperature/Humidity System

Key:—1. NTC thermistor—2. PTC thermistor—3. Temperature/humidity conditions—Room temperature, dehumidified storage—4. Sensor used—5. Raw materials—6. Receiving of raw materials—7. Blending—8. Drying—9. Temporary baking/crushing—10. Drying—11. Pelletizing/forming—12. Room temperature—250°C thermocouple (CRC)—Room temperature—1,200°C thermocouple (PR)—Room temperature—250°C thermocouple (CRC)—13. Rubber press—14. Baking—15. Annealing—16. Room temperature—1,600°C thermocouple, Seger cone—Room temperature—800°C thermocouple (CA)—17. Slicing—18. Plating liquid—19. Plating—20. Storing at cool dark place—Room temperature—100°C thermocouple (CRC)—Room temperature—1,000°C thermocouple (PR)—21. Electrode paste—22. Electrode baking—23. Cutting—24. Aging—25. Replacing jigs—26. Welding—27. Lead wire—28. Bonding—29. Bonding paste—30. Baking—31. Glass—32. Glass sealing—33. Room temperature—1,000°C thermocouple (PR)—34. Plating liquid—35. Lead wire plating—36. Resistance value selection—37. Reliability confirmation—38. Resistance value inspection—39. Atmospheric control; 10^{-4} Torr; Storing in cool dark place; Room temperature—100°C thermocouple (CRC); -65 to +150°C crystal temperature instrument, thermocouple (CRC)

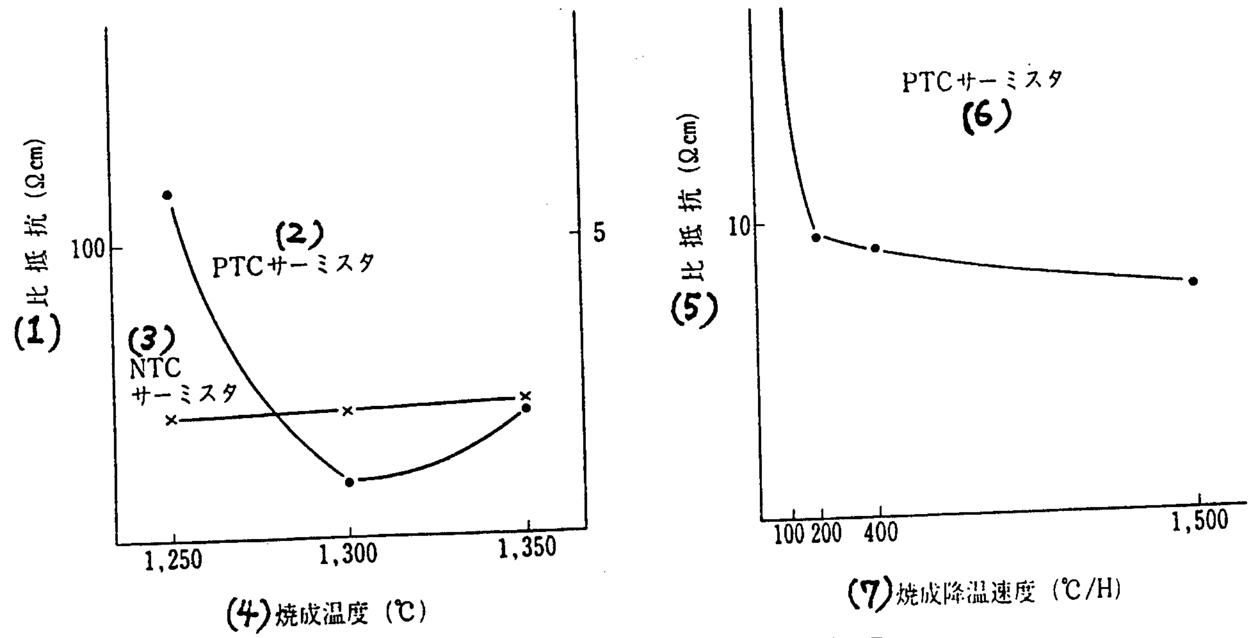


Fig. 3 Temperature and Characteristics at Baking Process

Key:—1. Resistivity—2. PTC thermistor—3. NTC thermistor—4. Baking temperature—5. Resistivity—6. PTC thermistor—7. Baking temperature lowering rate

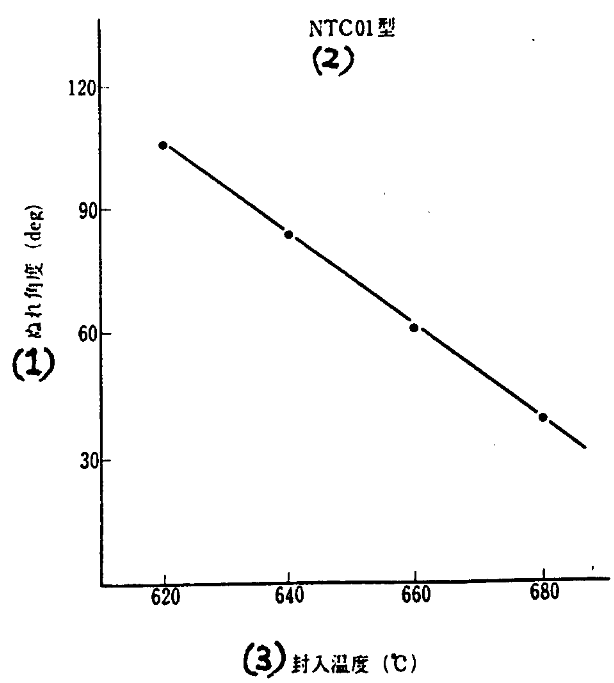


Fig. 4 Relation Between Glass Sealing Wetting Angle and Sealing Temperature

Key:—1. Wetting—2. NTC01 type—3. Sealing temperature

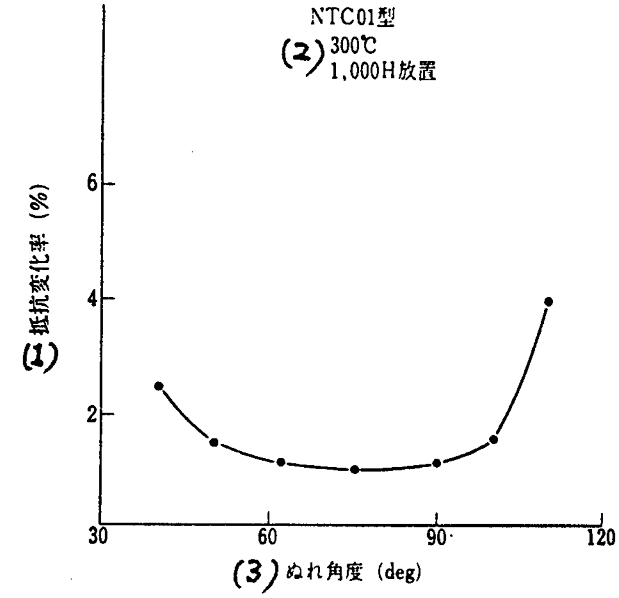


Fig. 5 Relation Between Glass-sealing Wetting Angle and Sealing Temperature

Key:—1. Resistivity change rate—2. NTC01 type; 300°C; Left standing for 1,000 hours—3. Wetting angle

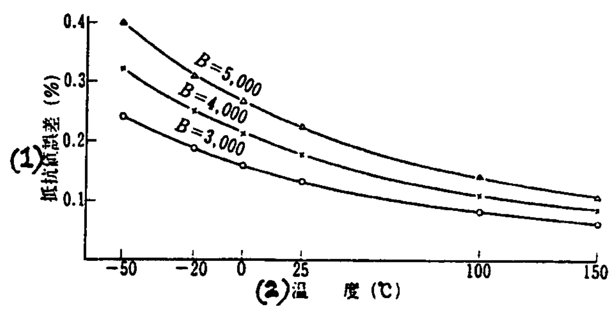


Fig. 6 Resistance Value Errors Corresponding to Temperature Instrument Accuracy

Key:—1. Resistance value errors—2. Temperature

Table 1. Sensor Selection Standard

	Drying	Baking	Electrode baking	Bonding agent baking	Glass sealing	Measurement of resistance
Measuring temperature range	Room temp. to 250C	1,600°C	1.000°C	800°C	700°C	-65 to 150°C
Measuring medium	Air	Air, gas	Air, gas	Air	Air, gas	liquid
Detection accuracy	2°C	4°C	2.5°C	2°C	2°C	0.04°C
Interchangeability	0	0	0	0	0	0
Unit function	Heating, indication	—	—	—	—	Heating/cooling indication
Movement of medium	Forced flow	Standing	—	—	Standing or gas flow	Forced flow
Temperature change rate	200°C/day	400°C/H	400°C/H	400°C/H	600°CH	Constant temp
Absolute or relative value of temperature	Relative value	Relative value	Relative value	Relative value	Relative value	Absolute value
Corresponding sensor	Thermocouple Liquid expansion type	Thermocouple	—	—	—	Crystal temperature instrument
	Bimetal type					

4. Future Technical Problems

With the manufacture of highly accurate ceramics devices, the manufacturing process must be highly controlled. In particular, the sintering process, which can be said to most strongly affect the performance of ceramics, is where atmosphere and temperature are becoming factors which must be controlled. In other words, it is necessary to properly control atmosphere, oxygen concentration, and humidity to rearrange the solid solution ions composing ceramics, in the process of baking and temperature lowering. Such control makes it possible to obtain ceramics having a microscopic structure designed in a good, reproducible manner. However, since the manufacturing process for ceramics devices includes many plant-like elements, a considerable amount of investment is required for environmental control. Therefore, to improve the efficiency of environmental control, it is necessary to thoroughly study the relation between the electrical performance and microscopic structure ofceramics and the manufacturing process factors determining this relation. In other words, it is becoming more indispensible to thoroughly study ceramics characterization and to complete it to further advance manufacturing specifications.

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Japan-Canada Complementarity Study

43070715 Tokyo JAPAN-CANADA COMPLEMENTARITY STUDY COMMITTEE in English Summer 89 pp 1-12

[Text]

JAPAN-CANADA COMPLEMENTARITY STUDY

A Joint Study for Enhanced Cooperation in the Field of Science and Technology Between Japan and Canada

The Report to the Prime Ministers of Japan and Canada

His Excellency Sousuke Uno

The Right Honourable Brian Mulroney

from the Japan-Canada Complementarity Study Committee

Dr. Geraldine Kenney-Wallace, Chairman, Dr. Richard Bolton, Dr. John Webster, Dr. Hugh Wynne-Edwards, Dr. Michio Okamoto, Dr. Hiroo Kawata, Dr. Masato Yamano, Dr. Hiroyuki Yoshikawa

Main Recommendations

As a result of our assessment of past and current science and technology cooperation between Japan and Canada, and of our extensive consultations with scientists and engineers in both countries, and of our own deliberations, we respectfully submit for your consideration the following main recommendations bearing on the principal areas and effective mechanisms for future S&T cooperation between Japan and Canada.

We recommend:

1. that the governments of Japan and Canada publicly and quickly commit themselves to a new, imaginative, and enhanced program of bilateral R&D activities which builds upon the existing bilateral S&T agreement. The key characteristics of the program that we urge you to support are:

—dedication to excellence

—emphasis on young researchers

—concentration on creative ideas and "frontier" science and technology

2. that Japan and Canada immediately pursue a program of enhanced cooperation in the following six broad "umbrella" areas of science and technology. These areas of equal importance are:

—advanced materials and biomaterials

—biotechnology and biosciences

—oceanography and ocean engineering

—space science, technology and cosmology

— dvanced manufacturing (artificial intelligence (AI) and robotics), microelectronics, communications and photonics

— ustainable development and environmental management.

In order to launch the new recommended program of S&T cooperation effectively and to capitalize on some major scientific developments, we further recommend that the following key areas from within the broad "umbrella" areas be singled out for immediate attention. These are:

I. Advanced materials and biomaterials

1. Thin film superconductors, growth and characteristics; oxide superconductors

2. Structural advanced ceramics and ceramic coated implants

3. Experimental and theoretical aspects of complex interfaces and surfaces

II. Biotechnology and biosciences

1. Biochemical engineering

2. Fermentation technology

3. Medical biotechnology

4. Applications of biotechnology to fisheries, forestry, and agriculture

III. Oceanography and ocean engineering

1. North Pacific Ocean

2. Advanced technology

IV. Space science, technology, and cosmology

1. Materials for space

2. Astronomy in space

3. Space plasma physics

V. Advanced manufacturing

1. Microstructures and their microelectronic functions

2. Advanced processing and manufacturing technologies

3. Lasers and photonics

VI. Sustainable development and environmental management

1. Acidification processes, environmental effects of acidification, and engineering solutions

2. The influence of the North Polar Region on global climatic change and global scale simulation

3. Atmospheric trace gases, dispersion (micro- and meso-scale), and environmental observation from space

3. that the program make a flexible and wise use of many specific generic means of cooperation. These include:

— exchange of information

— bi-national post-doctoral programs and exchange of graduate students, junior and senior scientists and engineers

— bi-national topical workshops, conferences and meetings in selected "umbrella" areas

— access to major S&T facilities in both countries

— cooperative R&D projects

These should be applied according to need and circumstance. Continuing discussions on potential and future cooperation will be the most effective way of determining their utilization within each broad S&T "umbrella" area.

4. that in order to achieve enhanced cooperation in the appropriate areas and with the mechanisms we have described, the necessary financial resources should be identified in order to trigger cooperation.

5. that there be created a small, strong and prestigious science advisory board to be known as the Bi-National Advisory Board on S&T. The responsibility of the Bi-National Advisory Board on S&T will be to review on a continuing basis the overall science and technology relationship between Japan and Canada and to advise the Japan-Canada Joint Committee on Scientific and Technological cooperation on issues concerning that relationship. Some suggested specific functions of the Bi-National Advisory Board on S&T are provided in the Main Report.

Should the Bi-National Advisory Board be established, it would be desirable, in order to maintain the continuity and momentum generated in Japan and Canada by "The Complementarity Study" to model it on the present Japan-Canada Committee (CJC).

The context for these recommendations is provided by our main report which follows.

MAIN REPORT

Introduction

In the spring of 1988 the Science Council of Canada was pleased to respond to a request from the Prime Ministers of Japan and Canada to undertake a study described as "The Joint Study on Cooperation in the Field of Science and Technology Between Japan and Canada." The Science Council of Canada was asked specifically to identify "principal areas and effective mechanisms for future cooperation, under the Agreement Between the Two Governments on Cooperation in Science and Technology signed at Tokyo on May 7, 1986," while taking account of "...current science and technology cooperation between the two countries." Dr. Geraldine Kenney-Wallace, Chairman of the Science Council of Canada, was invited to lead the study on behalf of both countries. At her request, Dr. Michio Okamoto, member of the Japanese Prime Minister's Council for Science and Technology, was the leading Japanese member.

Approach and General Principles

Approach

The Committee recognized from the outset that it was responsible for making definitive recommendations on how to promote the successful cooperation of scientists and engineers. Knowing the importance of genuine cooperation, the Committee ensured that in developing its recommendations, it received advice from the people who would ultimately be responsible for the success or failure of future cooperation. Hence, it consulted widely among leading Japanese and Canadian scientists and engineers.

The work of the Committee has consisted of four elements, namely:

1. Identifying the principles on which strengthened cooperation should be based.

2. Examining and assessing Japan-Canada cooperation up to the present.

3. Soliciting the views of eminent scientists and engineers in Japan and Canada and promoting bi-national discussions within Japan and Canada, including visits to major research institutions in order to obtain the advice of practitioners on areas and means of cooperation.

4. Developing, based on knowledge gained from the steps outlined above, a report that focuses on the initial areas of cooperation and the mechanisms for the implementation and monitoring of the proposed program of cooperation in science and technology.

General Principles

At the outset, the CJC identified excellence and strength as its goals and agreed to focus on inter-disciplinary opportunities. It also chose to work at the frontiers of its imagination and to be international in perspective.

The Committee, and the Japanese and Canadian scientists and engineers who have so generously assisted CJC, are certain that the identification of complementing strengths and excellence in Japan and Canada is the keystone that will ensure and enhance successful cooperation in the future. This is a guiding thread that has run through the entire study.

It is our conviction that in future cooperation the accent must be on youth. Young scientists and engineers are more mobile and more capable of building the long-term

working relationships and friendships that provide the best foundation for sustained successful cooperation.

Cooperation should be facilitated within the following broad categories of research, viz. pure basic research, applied basic research (i.e., basic research undertaken with the objective of confirming or disproving the possibilities of practical applications), applied research, and development work in areas of great risk.

Last, but not least, we are of the opinion that cooperation in S&T will more readily and effectively occur when participants have an understanding of each other's language and culture. We urge both Japan and Canada to examine closely the adequacy of current education programs to promote for scientists and engineers familiarity and understanding of each other's culture and language.

The Areas of Cooperation

We recommend that Japan and Canada immediately pursue a program of strengthened S&T cooperation in the following six broad areas of science and technology. These areas, which are of equal importance, are:

- advanced materials and biomaterials
- biotechnology and biosciences
- oceanography and ocean engineering
- space science, technology, and cosmology
- advanced manufacturing (artificial intelligence (AI), and robotics), microelectronics, communications, and photonics
- sustainable development and environmental management.

The focus of cooperation over the next five years in these key broad "umbrella" areas should enhance the complementary strengths of Japan and Canada. Within them, we have identified forty "medium-breadth" areas, which we regard as especially promising for cooperation (see appended material from the CJC workshops).

It is impossible to launch the new program of S&T cooperation simultaneously in all of these fields. In order to be sure of effecting a strong start and to capitalize on some major scientific developments, we recommend that the following key areas from within the broad "umbrella" areas be singled out for immediate attention.

These are:

I. Advanced materials and biomaterials

1. Thin film superconductors, growth and characteristics; oxide superconductors

2. Structural advanced ceramics and ceramic coated implants

3. Experimental and theoretical aspects of complex interfaces and surfaces

II. Biotechnology and biosciences

1. Biochemical engineering

2. Fermentation technology

3. Medical biotechnology

4. Applications of biotechnology to fisheries, forestry, and agriculture

III. Oceanography and ocean engineering

1. North Pacific Ocean

2. Advanced technology

IV. Space science, technology, and cosmology

1. Materials for space

2. Astronomy in space

3. Space plasma physics

V. Advanced manufacturing

1. Microstructures and their microelectronic functions

2. Advanced processing and manufacturing technologies

3. Lasers and photonics

VI. Sustainable development and environmental management

1. Acidification processes, environmental effects of acidification, and engineering solutions

2. The influence of the North Polar Region on global climatic change and global scale simulation

3. Atmospheric trace gases, dispersion (micro- and meso-scale), and environmental observation from space

[Some description of these areas can be found in the reports of the "Mobile Workshops" contained in the Annex.]

Criteria used in the selection of these areas included:

(1) high scientific potential, (2) scientists in Japan and Canada are highly qualified and motivated, (3) some projects can be undertaken only on a unique cooperative bi-national basis.

Because of the dynamic nature of scientific discovery and the rapidity of technological change, the Committee recognizes that a program of cooperation must be regularly under review and evaluation, and is in no doubt that topics and fields will be added and removed. This will reflect changing scientific frontiers, resource availability and opportunity, national needs, and the commitment of the members of the S&T community over the medium- and long-term timescale.

The Mechanisms of Cooperation

In order to exploit the opportunities that cooperation in the recommended areas will provide, we recommend that Japan and Canada publicly and quickly commit themselves to a new and imaginative, enhanced program of bilateral R&D activities that builds upon the existing bilateral S&T agreement. The CJC strongly emphasizes the need to sow the seeds now for the future.

The distinguishing characteristics of the program that we recommend are:

- dedication to excellence

emphasis on young researchers

concentration on creative ideas and "frontier" science and technology.

We recommend that the program make a flexible and wise use of many specific generic means of cooperation. These include:

- exchange of information

bi-national post-doctoral programs and exchange of graduate students, junior and senior scientists and engineers

bi-national topical workshops, conferences and meetings in selected "umbrella" areas

access to major S&T facilities in both countries

cooperative R&D projects.

It is not appropriate to differentiate between these means in terms of their significance: they all have a role to play in cooperation. Continuing discussions on potential and future cooperation will be the most effective way of determining their utilization.

Financial resources are crucial! It is recognized by the CJC that without firm investment of the appropriate financial resources by both countries, it will not be possible to promote further cooperation in science and technology. Hence, in order to fulfill the objectives of our respective Prime Ministers, we have identified specific complementary and preferred areas of research cooperation and we recommend that the necessary financial resources be identified to trigger this cooperation.

Evidence shows that lack of financial resources and lack of a focus for scientific expert advice have been the major reasons for the failure to tap fully the potential of existing S&T agreement between our countries.

To overcome the latter problem, the CJC recommends the creation of a small, strong and prestigious science advisory board to be known as the Bi-National Advisory Board on S&T. The responsibility of the Bi-National Advisory Board on S&T will be to review on a continuing basis, the overall science and technology relationship between Japan and Canada and to advise the Japan-Canada Joint Committee on Scientific and Technological Cooperation on issues concerning the relationship.

Suggested specific functions of the Bi-National Advisory Board on S&T include:

A. Identifying issues of importance to the overall science and technology relationship between the two countries and making appropriate recommendations to the Japan-Canada Joint Committee on Scientific and Technological Cooperation.

B. Reviewing major advances in science and technology in the two countries and recommending to the Japan-Canada Joint Committee on Scientific and Technological Cooperation priority areas for bilateral cooperation.

C. Reviewing the mechanisms of science and technology cooperation between the two countries in respect to their effectiveness in strengthening the overall science and technology relationship, and making appropriate recommendations to the Japan-Canada Joint Committee on Scientific and Technological Cooperation.

D. Identifying and recommending to the Japan-Canada Joint Committee on Scientific and Technological Cooperation approaches to enhance comparable access to research and training opportunities, facilities, expertise, data, and results, taking into consideration each nation's research and development systems, institutions and policies.

Should the Bi-National Advisory Board be established, it would be desirable, in order to maintain the continuity and momentum generated in Japan and Canada by "The Complementarity Study" to model it on the present Japan-Canada Committee (CJC).

Postscript

Serving on the Japan-Canada Committee has been both a privilege and a pleasure for all of us. Canadian and Japanese Committee members, as well as the many scientists and engineers who have worked with us, have come to know each other as persons and started to appreciate, at least a little, some aspects of each other's culture. In this regard, therefore, our experience is a model for the experience that we hope an increasing number of our young scientists and engineers will enjoy in the future. It is our earnest hope that scientific and technological cooperation of mutual benefit to both countries, as well as the global community, will grow and strengthen in the future. But in addition to that, the bonds of friendship and mutual understanding, which will surely be forged in a program of strengthened cooperation between our countries, will be as important as the scientific, technological, trade and economic benefits. Our world is one with many problems that will never be solved by nations working alone, but only by

nations working in concert. The laws of nature deem science and engineering to be intrinsically international activities. Scientists and engineers from all nations will play a crucial role in solving global problems. Their ability to work effectively together will depend greatly on their possession of mutual respect for and understanding of each other's cultures and values. Let us give excellent young Japanese and Canadian scientists and engineers the opportunity to build the bonds of respect and friendship and create the mutual understanding that is essential to the creation of a peaceful, harmonious, prosperous, sustainable global society and environment.

Japan-Canada Complementarity Study Committee (CJC)

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Dr. Hiroyuki Yoshikawa, Professor of Machine Design, Department of Precision Machinery Engineering, The University of Tokyo, Tokyo, Japan.

MPT Improving VLBI Technology To Study Continental Shift, Plate Movement

TSUSHIN KOGYO in Japanese 25 Sep 89 p 2

[Summary] The Telecommunications Laboratory of the Ministry of Posts and Telecommunications, which has been working to perfect a VLBI (Very Long Baseline Interferometry) observation network, has succeeded in determining that the baseline length between the Kashima home station and the station in southern Torishima is 181,227,066.0 cm. VLBI has attracted worldwide attention as a means to measure continental shifts and plate movement. In Japan, the plan is to improve the VLBI system over the next five years in order to detect movement in the crustal plate around Japan.

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